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THE

ANATOMY OF THE JOINTS OF MAN

FRONTISPIECE

THE ANATOMY

OF

THE JOINTS OF MAN

BY

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TO

THE PAST AND PRESENT STUDENTS

OF

THE MIDDLESEX HOSPITAL,

IN RECOGNITION OF THE GOOD FEELING

AND UNVARYING COURTESY

THEY HAVE AT ALL TIMES SHOWN HIM,

AND AS A TESTIMONY OF HIS SINCERE INTEREST IN THEIR

PERSONAL WELFARE AND PROFESSIONAL SUCCESS,

This Work is Dedicated

BY THE AUTHOR.

PREFACE.

To those who are or have been engaged in anatomical teaching, the appearance of a new work on the "Anatomy of the Joints" will not be surprising. For some years past it has seemed to me that such a book was needed; and I have reason for thinking that many others have, like myself, felt the deficiency to the surgeon, as well as to the anatomical student and teacher, of a comprehensive description of the joints.

It has hitherto been customary to describe, in the various text-books of anatomy, under the head of "The Joints," the ligaments and synovial membranes only, without giving any account of the bursæ and muscles in relation with them, or of the articular ends of the bones; and without any reference whatever, except in the case of the larger joints, to the arteries and nerves which supply, or to the movements which are permitted at, the articulations.

The consequence of this has been that the student has had to look under one section for the ligaments, under another for the bones, under a third for the blood supply, and so on; but by the arrangement adopted in this treatise, all the various structures of a joint are brought under notice together, and thereby much loss of time and inconvenience will, it is hoped, be spared the reader. It has further been my endeavour to connect the study of the anatomical structures with that of their physiological actions and uses, the correct knowledge of the one being necessary for a proper understanding of the other.

In composing this book, the plan I have followed has been to write independent descriptions from my own observations and dissections, and afterwards to enlarge upon and improve them by reference to the works of some of the best anatomical authors, more especially those of Bourgery, Weitbrecht, Goodsir, Wood, Humphry, and the various English text-books.

It has been stated sometime that only two things justify the publication of a book, viz., the author must either communicate something new, or he must have a new method of stating what is already known. While conscious of the many shortcomings of this work, I am, I think, justified in introducing it to the profession on the second ground; but I shall be more than compensated for somewhat prolonged labour if it be considered by capable judges that I have also added to the accuracy and fulness of previous descriptions of some of the joints.

To my friend, Mr. Davies-Colley, Lecturer on Anatomy at Guy's Hospital, my best thanks are due, both for the care with which he has shared with me the labour of correcting for the press, and also for many valuable criticisms and suggestions.

The illustrations have been made chiefly from my own dissections; those of the bursæ, however, are copies from Monro's work. Two of the woodcuts are after figures in Ward's Osteology, and one is copied from the Encyclopædia of Anatomy.

Not possessing the power of using the pencil and brush, like my predecessor Sir C. Bell, I have been fortunate in obtaining the assistance of my colleague Mr. Hensman, and Mr. Steele, each of whom has bestowed great patience and pains upon the drawings.

The plates have been prepared by Messrs. West and Co., and I cannot omit thanking Mr. Knight of that firm for the general fidelity with which they have been executed.

HENRY MORRIS.

2, Mansfield Street, Cavendish Square,
January, 1879.

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ANATOMY OF THE JOINTS.

PART I.

CHAPTER I.

PARTS ENTERING INTO THE CONSTRUCTION OF JOINTS.

It may with truth be said that every kind of structure in, and every organ of, the body is to a certain extent subservient to the perfection and uses of the joints. All animals, indeed all living things, live by movement of some kind; and in animals which possess joints, movement by means of joints is necessary to the continuance of life.

Plants and animals alike require, in order to live, the movement within their tissues of air, of water containing air, of food particles, of blood or of some equivalent fluid; but in animals which respire by lungs, which move from place to place, which seize their prey and masticate their food, the anatomical and physiological integrity of joints is an absolute requirement of existence.

Man must walk, must lie down and rise up, must turn from side to side; scarcely one of the ordinary conditions of his life could be fulfilled were he deprived of the use of his hands and forearms; did he not move his ribs, respiration would soon cease, and if he were not to masticate or chew he must quickly die. By the beating of his heart and the circulation of his blood, the joints are nourished and repaired. He takes food because he must eat to live, but to eat he must move, and so even in this respect he moves to live. His senses and intellect, the ear, eye, taste, touch, and brain, are from the first employed to guide his movements, and in return they gather information and obtain experience for him by the action of his joints.

His mind is furnished through his senses, and his senses are educated through the movements of his joints, for how limited would have been his knowledge of sights and sounds without the agency of his articulations; while taste and touch, extension and distance, must have been altogether unknown to him. Thus, then, it may be said that Life is movement, and in the higher animals, movement by means of joints.

In a work on the anatomy of the articulations, it will be well to give a brief separate consideration to each of the structures which enter into the composition of a joint. The bones, cartilages, and muscles—*i.e.*, the parts moved and the agents of movement; the various ligamentous bands and membranes uniting the individual bones, affording them security and firmness, lubricating their articular surfaces, and thereby giving smoothness and ease to their motions upon each other; the bloodvessels which bring the nutriment; and the nerves which give sensibility to the tissues, control nutrition, and influence the muscles moving the head, trunk, and limbs, must all be taken into account in making a complete study of the joints, because each and all are necessary to the functions of the joints.

Bones constitute the basis of most joints, and are the parts which are moved upon one another. The surfaces which are opposed are articular surfaces, and in the long bones these are expanded much beyond the dimensions of the shaft, for the greater security and strength of the joints and for the leverage of the muscles moving them. As a rule, long bones articulate at their ends, short bones at different points of their surfaces, and flat bones at their edges. Most bones are curved and twisted in more than one direction; those of the limbs are oblique with regard to one another, and with regard to the corresponding bones of the opposite side, the result of which is that the joints are so arranged that the movements of the limbs on the two sides of the body are not in parallel planes. Take for example the movements of the forearm on the arm at the elbow, or of the hand on the forearm. Gracefulness of movement is the effect of this obliquity.

Upon the shape and configuration of the articular surfaces depend in a great degree the functions and mobility of the joints; but though modified by the shape of the bones, the movements which are possible are rarely if ever checked or limited by it. Either the tension of ligaments or the apposition of soft overlying structures stops movement before the margins of the bones touch one another; the advantage of which is that damage to the articulations cannot arise by the sudden contact of the constituent bones. There is generally a degree of correspondence between the osseous surfaces and the other structures of a joint. The formation of the bones is somewhat modified in accordance with the requirements of the joints; thus the shell of compact bone which forms the articular surface is very dense and strong, and well adapted to bear pressure, contains no Haversian canals, has very large lacunæ, no canaliculi, and the vessels of the cancellous tissue which it covers in, turn back without penetrating it.

The shape and configuration of the different processes of the articular parts of bones is a most important consideration in the study of joints. They regulate the function of the articulation, modify its liability to injury, and are all-important in the clinical examination of an injured part.

Cartilage.—The cartilage of joints is of two kinds, hyaline and white fibrous.

A. *Hyaline cartilage* as found in the joints is adapted by its polished smoothness to reduce friction to a minimum, by its elasticity to prevent jarring of one bone upon another; while by its being devoid of extreme sensation the movements and pressure to which it is subjected occur without causing pain, while yet it is very sensitive to the presence of a foreign body, such as a loose cartilage in a joint. It is of pearly whiteness, solid, but less hard than bone; it is composed almost entirely of animal matter, whereas bone has a considerable quantity of earthy salts in its composition. Like bone it sometimes forms the essential element or basis of a joint, as in the chondro-sternal and the costo-chondral articulations, and is then covered by a fibrous membrane resembling the covering of bone, and called perichondrium. Its more usual disposition is as a covering to the articular surfaces of bone.

(1.) Articular cartilage is the name given to hyaline cartilage where it invests the articular ends of the bones. It serves to reduce friction, to moderate the force of pressure on the bones, and to confer slight elasticity. It varies much in thickness, being thickest at the points at which most pressure has to be borne. By one surface it is connected with bone so firmly as to seem like a continuous structure: its other surface is directed towards the cavity of the joint, and in the fœtus is coated by a thin film of epithelium continuous with the epithelium of the synovial membrane of the articulation; but when the joint is brought much into use and as age advances, this film of epithelium is gradually worn away by friction up to the margin of the cartilage. The cartilage terminates abruptly, and extends upon the bones no further than friction requires it.

(2.) Another form of "hyaline cartilage of joints" is found in the *costal cartilages* of the thorax and the *xiphoid cartilage* of the sternum. It is the form of hyaline cartilage which is substituted for bone where flexibility is required. The cartilages of the ribs form the medium of union between flat bones—viz., the ribs and the sternum. It resembles articular cartilage in this respect, that at one end it is continuous with bone—*i.e.*, with the anterior extremity of the rib, while at the other it is in relation with a synovial cavity—*i.e.*, the chondro-sternal joint. The ends of the costal cartilages correspond to the surfaces, and the parts between the ends to the margins of the articular cartilage; but there is this difference, that the prolonged margins are covered over by perichondrium, which does not exist upon the margins of the articular variety. The use of these cartilages is to unite the ribs and sternum, and thus to complete the wall of the chest, part of the framework of which it forms; while at the same time that it protects the contents of the thoracic cavity it allows of movements, and is capable of yielding, instead of breaking, under pressure.

B. *White Fibrous Cartilage of Joints.*—White fibrous cartilage resembles in structure and texture both fibrous tissue, such as ligament, and hyaline cartilage, and therefore partakes of the physical properties of each. It has to a certain extent the strength and flexibility of the one and the elasticity of the other, and may be considered as a link between the two.

It occurs in joints in different forms: (1) inter-articular fibrocartilage, such as is found in the temporo-maxillary, sterno-clavicular, inferior radio-ulnar, the knee, and sometimes the acromio-clavicular articulations. They are confined to diarthrodial joints. They are nearly free, being connected only at their edges with the ligamentous and synovial tissues of the joint; their surfaces are unattached and are interposed between the articular surfaces of bone, so as in some cases to divide the joint into two distinct cavities. This is usually the case in the temporo-maxillary and sterno-clavicular joints. In the knee there are two imperfect fibro-cartilages, which, instead of completely separating the bones, merely project into the articulation and allow the synovial membrane to be continued as a thin epithelial film over their surfaces. If, however, we consider these two imperfect cartilages as one, having a perforation at its centre, we find a strong analogy between them and the occasional condition of the most perfect inter-articular cartilages—viz., an opening sometimes exists at the thin central part allowing of a communication between the two portions of the joint cavity which the cartilage separates; or, in other words, owing to this perforation of the fibro-cartilage, what would otherwise be *two* shut sacs becomes one. They occur in joints at which there is frequent and violent motion, and serve the purpose, owing to their elasticity, of breaking the shock of concussions; they act as adjusters to adapt dissimilar bony surfaces to one another; increase the extent and variety of motion by allowing it to take place at one time between the cartilage and the bone on one side, and at another between the cartilage and the bone on the other side; and lastly, they add to the strength and security of the joint.

(2.) " Circumferential or marginal" fibro-cartilage occurs on the edges of the acetabulum and glenoid fossa, and serves to deepen the sockets for the reception of the heads of the femur and humerus respectively. In this form they are found only in that variety of diarthrodial joints known as " ball and socket." Another form of what may be called marginal, though not circumferential, fibro-cartilage is to be seen in the joints of the fingers. Here small plates of white fibro-cartilage, closely connected with the base of one phalanx, serve to deepen the socket for the reception of the head of the bone above it, and to add to the stability of the articulation.

(3.) A third form of white fibro-cartilage is the " connecting." It is found interposed between, but binding together in a solid manner, two bones, as in the case of the intervertebral substances and bodies of the vertebræ. These connecting fibro-cartilages occur only in amphiarthrodial joints, and the amount of motion which is possible between the bones so bound together is only as much as the elasticity and flexibility of the uniting fibro-cartilage will allow. Although limited, yet the degree of motion at these joints is often far from being insignificant, whilst they possess, through this fibro-cartilaginous union, a great degree of strength and a capacity for resisting violent concussions, together with a tendency to assume their natural position after having been disturbed therefrom by muscular action or other forces. The easy flexibility and the great strength of the spinal column sufficiently attest the utility of this structure.

Besides the bodies of the vertebræ, there are other examples in the skeleton of bone being united with bone by means of "connecting cartilages." Such are found in the pelvis at the symphysis pubis and sacro-iliac synchondrosis. In structure these latter are essentially fibro-cartilages, for they have fibres in their matrix, but the proportion of cells to matrix is much greater in them than in the fibro-cartilaginous portions of the intervertebral substances. But this is only a matter of more or less, and at the other extreme are the circumferential fibro-cartilages, which are composed almost entirely of fibres, with sometimes hardly a trace of cells. There is, however, this difference in the joints formed by the more fibrous and the more cellular connecting cartilages, that the former allow a manifest degree of motion and compression, while the other usually permit only a minimum amount of yielding; but at periods, as during pregnancy, the pelvic symphysial cartilages swell up and enlarge considerably, and are then capable of a considerably increased amount of yielding. A preparation which I obtained from a woman in the seventh month of pregnancy, and placed in the Middlesex Hospital Museum, shows the great thickness which these substances sometimes attain.

Ligaments.—Ligaments are strong fibrous bands passing from one bone to another, and in doing so they blend with the margins of fibro-cartilages which separate the bones, and give support and protection to the synovial lining of joints when such exist. They give stability to the skeleton at the points of junction of bone with bone, or bone with cartilage, and serve to limit and control the motions of the articulations; they sometimes extend between different parts of the same bone, as in the case of the transverse ligament of the acetabulum, the supra-spinous, and the coraco-acromial ligaments of the scapula.

Like hyaline and white fibro-cartilage, ligamentous tissue is to be found in other parts of the body besides at the joints, and serving other purposes besides joining bone with bone or cartilage. For instance, it occurs in the form of the so-called annular ligaments, which serve the purpose (sometimes exclusively) of tying down tendons as they pass to their insertions; and in the form of tendon itself, ligamentous tissue intervenes between muscular fibres and bone, and serves to fix the former to the latter.

Here we have only to do with articular ligamentous tissue, or ligaments commonly so called. They are composed of fasciculi of inelastic parallel and crossing fibres of a white, silvery colour, and covered over with a fine envelope of cellular tissue. They vary in thickness, length, strength, and shape, according to the form and motions of the joint. They differ in number in the several joints, sometimes being numerous, at others few. They are intimately connected at their attached extremities with the periosteum of the bones, and are indeed sometimes regarded as direct and thickened continuations of that membrane from one bone to another. Though of the same structure they differ in their deep relations, for while periosteum is always intimately adherent to bone, the ligaments are either lined by synovial membrane or attached to intermediate fibro-cartilage. The direction of the fibres of ligaments varies at different parts of the same joint, and depends upon the direction of the motions that each has to control. Between the fibres of the ligaments the minute bloodvessels of the joint penetrate so as to reach the external aspect of the synovial membrane, upon which, as well as between it and the bones at the margins of articular cartilage, they ramify.

Articular ligaments may conveniently be divided into four classes—viz.: 1. Those which connect the bones of diarthrodial joints together, and in doing so form fibrous envelopes for the articulation. Of these we have good examples in the capsular ligaments of the ball and socket joints—viz., the hip and shoulder, and also in those less imperfect capsules surrounding such joints as the elbow, knee, and ankle. It is often the custom, and is always convenient, to speak of these less perfect capsules as consisting of anterior and posterior and lateral ligamentous bands, but these bands are always loosely connected with each other by intervening fibres. Even the most perfect capsules are thickened in places by superadded bands of fibres like the coraco-humeral ligament of the shoulder and the ilio-femoral of the hip. Some of the ligaments of this class wind round the end of a bone like a ring, as the coronary ligament does round the head of the radius, and the transverse ligament round the odontoid process. 2. Those which connect the slightly movable or amphiarthrodial joints at which the union between the bones is established by a connecting cartilage. They consist of short fibres passing in different ways across from bone to bone, sometimes transversely, sometimes obliquely, but always in a manner that will give strength and limit movement. Instances of this sort exist at the symphysis of the pelvis and along the front and back of the bodies of the vertebræ. 3. Certain ligaments exist within the ligamentous capsules of a joint, though not within the cavity of the synovial sac. They serve to connect together the bones between which they pass, and to limit motion. They are called inter-articular ligaments, and are found in the knee-joint as crucial ligaments, and in the hip as the round ligament—the ligamentum teres. The latter in the human skeleton is insignificant in importance, whether we regard it as a means of uniting the bones or as a check to movement. 4. Some ligaments which are tightly extended between bones become still more tightly stretched as the bones are separated a little more widely from each other. They need therefore be elastic as well as flexible, a property not possessed by ordinary ligament. They are formed of yellow elastic instead of white fibres. By their elastic property they do away with the necessity of muscles as a means of restoring the parts to which they are attached to the state of rest after disturbance therefrom. They perhaps can hardly be said to be articular ligaments, yet they are important structures in connecting bony parts; they only exist between the laminæ or bony arches of the vertebræ.

Synovial membrane enters into the composition of all diarthrodial joints, and secretes a fluid which lubricates the surfaces and facilitates their movements. Except where the articular cartilage occurs the inner surfaces of joints are lined by synovial membrane. Usually they form closed sacs without any external openings, but as age advances and use becomes more frequent they sometimes communicate with one or other of the bursæ which are situated in the neighbourhood of some of the joints of the extremities. While the internal surface of the synovial membrane presents a smooth, glistening appearance, its external surface is rough and adherent to the ligamentous and osseous structures of the joint. In the natural state it is very thin, but frequently forms delicate folds which lie flat upon the edges of the cartilage, and thus project into the cavity of the joint. Enveloped between the layers of these folds are looped vessels and little masses of fat; they are usually covered with little processes like villi, which sometimes in diseased joints form polypous bodies hanging from the lining membrane, or overhanging the cartilages. Appended to the synovial membrane are masses of soft fat, which serve the purpose of filling up during movements the spaces left between the several tissues of the joints. These have been described by some of the older anatomists as glands whose purpose is the secretion of the synovial fluid, but they are now known not to be so. They project into the articulation between the bones, carrying the synovial membrane with them, or they lie in the hollows or depressions and notches of the bones of the joints, and form soft cushions for the contiguous bone. They are to be seen in the diagrams and in the dissection of such joints as the knee, ankle, metacarpo-phalangeal, and several others. The synovial membranes are very vascular, particularly near the margins of the articular cartilage, and in their fringes and folds; so also are the fatty masses above referred to, as witness those about the elbow, knee, and at the bottom of the acetabulum. They are also supplied with nerves and absorbents. In their minute structure they resemble other serous tissues, such as the pleura and pericardium. The synovial cavities are mapped out very early in the process of development; indeed as soon as the limbs are sufficiently advanced for any movement to occur between the segments of them. They have been seen quite distinct in the hip and shoulder joints before the third month of intra-uterine life.

Bursæ.—Where a tendon rubs over a bone, or beneath the integuments, or where a bone works so as to cause friction, a cavity or sac is formed in the cellular tissue between the two structures, and this sac contains fluid of the same kind as the synovia of joints. As age advances these sacs or bursæ often communicate with the cavity of a joint. They are met with as a rule only in the extremities. There are about 140 altogether in the body, 33 of which are in each upper extremity and 37 in each lower limb. They occur (1) between tendons and bones; (2) between tendons or superficial bony points and external parts; (3) between tendons and ligaments; (4) between contiguous tendons; (5) where processes of bones play on ligaments; (6) where one bone plays on another. Sometimes a bursa is common to two tendons, and then it divides where the tendons separate. Bursæ of contiguous tendons sometimes communicate. In their structure they resemble the synovial membranes, in that they have a wall of condensed cellular tissue lined by a thin, smooth secreting membrane. At the sides of bursæ, as well as of joints where no pressure or friction is exercised, adipose tissue abuts upon and is connected with the cellular wall; while from these fatty masses are suspended into the bursæ, as into the joints, fringes or folds containing within them bloodvessels, serving for the secretion of the lubricating fluid. By the pressure which the motions of the joints or tendons make upon these fimbriæ and fatty masses it is probable that the synovia is thrown out in greater or less quantity according to the requirements of the part; just as is the case with the salivary glands, more saliva being secreted by the motion of mastication or talking. Further, small cartilaginous bodies are often formed in the cavities of bursæ as well as of joints—of bursæ mucosæ and of bursæ synoviales; and such bodies, wherever situated, may be either movable or fixed.

Some of these sacs or bursæ have received the name of bursæ mucosæ, others of bursæ synoviales. In structure and uses they are identical; the former are large simple sacs, which may or may not be in connexion with tendons. They are to be found about the shoulder, hip, elbow, and knee joints, sometimes between tendons and the joint, sometimes between bony prominences and the integuments. The latter are ligamentary sheaths, along which tendons are conducted over such hinge joints as the ankle, wrist, toes, and fingers. These synovial bursæ are lined by a thin, smooth membrane, which is likewise reflected over the tendon, and secretes a synovia-like fluid, for the purpose of lubricating the surfaces during the play of the tendons within their sheaths.

There is a resemblance between the synovial sacs of joints and bursæ on the one hand, and the pleuræ, pericardium, and peritoneum on the other. In intimate structure, in the deposition of fatty tissue upon their exterior, and the presence of fat in the reduplications of these membranes, there are strong resemblances to the fat at the apex of the heart, in the omenta and the appendices epiploicæ of the colon. There are no fimbriæ or fringes projecting from these visceral membranes, and proportionately fewer bloodvessels ramify between them and the fat outside them. Small cartilaginous bodies are sometimes found in the cavity of at least one of them—viz., the human vaginalis testis.

The foregoing are the several parts, some or all of which are necessary for the construction of a joint. There still remain to be briefly considered the muscles which move it, the bloodvessels which nourish it, and the nerves which vivify it.

The Muscles are the agents of motion, and their use is to move one part of a joint upon another. Their relation to joints is very various. Some muscles pass over and move only one joint; others pass over and move several simultaneously or in quick succession. Much force is lost by the muscle passing over several joints; but it is a law that the more joints a muscle passes over the greater is the number of offices it has to perform, and the greater the number of joints it moves. Some muscles are inserted into bone near to an articulation, and this is attended with a loss of power, though with a rapidity of effect. Others are inserted at a distance from an articulation, and then there is less loss of power but less rapidity of motion. Such insertions are called short and long levers. The true levers of the body are very few in number, but they are those that most favour muscular power. The mastoid process, coronoid process of jaw, and the occiput are levers for the head; the spinous and transverse processes for the back; the trochanters, a tuberosity of the ischium, the crest of the ilium, the patella, the os calcis, and the arch of the foot, are levers for the lower limb; the acromion, olecranon, coronoid process of ulna, and pisiform bone of the hand, are levers for the upper limb. Speaking generally, there is nearly always some loss of muscular power owing either to the form of bone the muscle is intended to move, to the position of the insertion of the muscle, or to the obliquity of its direction, with respect to the motion to be effected. Nature often sacrifices power to fitness and to form, that the joints may be small and the limbs well proportioned; but she has supplied to muscles a quantity of vital contractile power, which more than compensates for the loss of mechanical advantage. In the words of that great surgeon, John Bell:—

"Nature is not seeking to compensate for want of power by the advantages of pulleys and levers and mechanical helps; nor is it in the forms of the parts that the Infinite Wisdom is to be found; for among other gifts such a portion of this spirit is given to man, that he has used the pulleys and lever, accelerations of motions, and all the mechanical powers that result from it; he has invented valves of infinite variety; he has anticipated all that he has found in the mechanism of the human body; but the living power which compensates for the want of levers, which allows everywhere power to be sacrificed to the beauty of form, which has strength in convulsive and violent actions to break the very bones; this is the act of Infinite Wisdom, on which our admiration should chiefly dwell."

Another and by no means an insignificant purpose served by muscles is to give strength and security to the union of bones at certain joints. Thus the hip is strengthened by the small rotator muscles (notably by the strong tendon of the obturator internus), and by the rectus and vastus tendons; the shoulder by the small muscles inserted into the tuberosities, and by the long tendon of the biceps. So in the case of the biceps and semimembranosus at the knee, the triceps at the elbow, the flexors and extensors at the wrist, and the crossing of the peroneus longus and tibialis posticus in the foot.

The muscles which surround an articulation afford almost as strong, in some cases even a stronger, power for restraining undue motion than the ligaments. About many of the joints we find one set of muscles acting as antagonisers to the others, so that when the first has acted upon a joint in one direction, the other set comes into play to check them by acting upon it in the opposite. Occasionally, however, this antagonising power is lost or overcome, and then the joint is dislocated by action of the muscles which move it.

The contraction of the surrounding muscles assists the ligaments of a joint, and the influence of atmospheric pressure, in preventing dislocations; and at the same time diminishes the strain upon the ligaments. Sprains occur when forces act upon the joints while the muscles are off their guard; for in the ordinary normal state the contraction of muscles probably prevents the ligaments from even being put upon the stretch.

A purpose served by muscles, and in some few instances (as in the subcrureus and subanconeus) the only purpose, is to act upon the capsule of the joint in certain positions, so as to prevent its being nipped between the edges of the bones.

A wise economy is seen in the mode of attachment of muscles to bones near a joint. *They are so disposed as never to strain the ligaments of a joint by tending to pull one bone from the other with which it articulates; but, on the contrary, add strength to the joint sometimes by decussating with the fibres of muscles of the opposite side, sometimes by the same muscle pulling tighter together the two bones of an articulation.* This statement, which I believe to have such a general application to the joints of the trunk as to be worthy of the name of a law, could be numerously illustrated. Take, for example, the decussation of the fibres of the muscles of the abdominal wall over the front of the symphysis pubis; the origin of the gluteus maximus, the latissimus dorsi, and the erector spinæ from both bones of the sacro-iliac synchondrosis; of the trapezius, deltoid, pectoralis major, and sterno-mastoid from each of the bones of the joints in connexion with which they are situated. Were it not for this, and had, for instance, the external oblique muscle of the abdomen not decussated over to the opposite side, or had not the deltoid arisen from both clavicle and acromion, a necessary result of their contraction would have been to strain the ligaments of the joints formed between those bones respectively. Many other examples illustrative of the same law might be adduced. As a further instance of the same design in sparing strain upon ligaments, the rotator muscles of the skull may be quoted. Here again we find a provision against such an immense strain, as would be caused by the dragging of the cranium, upon the ligaments of the occipito-atlantal joints during rotation of the head, if the muscles which turn the head and atlas round the odontoid process acted only on the atlas. Besides the muscles which are attached to the atlas, certain others are inserted at the skull, which, besides having a tendency to pull the head backwards or forwards, and to one side, are able to act in association with the muscles inserted into the transverse process of the atlas, and thus both skull and atlas are pulled upon at the same time, and the occipito-atlantal ligaments are saved the strain. These points will be further brought out in the description of the special joints, but they are of sufficient importance in the construction of the body to be mentioned here.

The Arteries.—Blood is supplied to all the structures of a joint, although some of the structures, such as articular cartilage, are what is called *non*-vascular—*i.e.*, have not bloodvessels penetrating their substance, but receive their nourishment from the vessels which are brought up to their surfaces. The synovial membrane is the most vascular structure of joints, and, to reach it, numerous minute arteries penetrate between the fibres of the ligaments to ramify in the fatty tissue about the joint, in the cellular tissue connecting the synovial with the ligamentous capsule, in the synovial membrane itself, as well as between its layers, where it forms fringes, fimbriæ, or mucous ligaments within a joint. The bloodvessels of a joint generally run quite up to the edges of the articular cartilages, and often form fine zones or circles around the articular margins of the bones; occasionally they may be seen passing over the edges and on to the surface of the cartilages and fibro-cartilages, as shown in the diagram of the semilunar cartilages of the knee-joint. It is a point of interest too in general and surgical anatomy, that it is in the neighbourhood of the articulations that the anastomoses between branches of different trunk vessels occur.

The Nerves.—It is very difficult, indeed often quite impossible, to trace with any certainty, even in well prepared and recent subjects, nerve filaments to the different tissues of a joint. But that some of the structures of joints are highly supplied with nerves is amply proved by the pain and startings caused by diseased joints. Often, however, and especially into the larger and more important joints, it is easy enough to follow nerve branches through the ligamentous fibres of the articulations. By way of generalisation, and on account of the great practical importance of a knowledge of the nerve sympathies of joints, it is well for the student and the practitioner to remember the great law, first pointed out by my friend and master, John Hilton, and subsequently, though perhaps quite independently, by Schroeder Van der Kolk—viz.:

"The same trunks of nerves whose branches supply the groups of muscles moving a joint, furnish also a distribution of nerves to the skin over the insertions of the same muscles, *and the interior of the joint receives its nerves from the same source.* This implies an accurate and consentaneous physiological harmony in these various co-operating structures."

Instances of this law will immediately occur to the advanced student, in the circumflex, subscapular, and supra-scapular nerves of the shoulder-joint, the suboccipital of the occipito-atlantal, the anterior crural of the hip, and many others.

CHAPTER II.

THE VARIETIES OF JOINTS.

THE name joint or articulation is given to the union of two or more bones; or of a bone with a cartilage, or of two or more cartilages. In most cases this union is effected by some intervening medium differing in structure from both bone and cartilage, but in some instances the bones are in the closest apposition, with no other connecting medium but their own proper covering—the periosteum.

In the previous chapter it has been stated that the structures which are immediately concerned in the union of the several bones of the skeleton with one another, are cartilage, fibro-cartilage, synovial membrane, and ligaments. Of these structures the only one that is found in all joints of the skeleton is bone itself, with perhaps a little intervening connective tissue. Even bone is not found in all the joints of the body—though it is in every joint of the skeleton—for the articulations of the larynx are formed between cartilages, not bone.

As the offices of joints are more complex and numerous, or what comes to the same thing, as the joint is more perfect, the greater is the number of the above structures which enter into its formation.

Thus, where (1) no movement at all is allowed, as in the cranial bones, the connexion is by simple close contact, or by overlapping of their edges, or by the invagination of one bone by another, or by direct apposition of their edges with a thin membranous layer of connective tissue—a sutural ligament—extending from the border of one to that of the other. Even this tissue—the sutural ligament—as age advances becomes entirely removed. (2.) Where only a slight amount of movement of one bone upon another is required, but great strength with some elasticity of union is also needed, the apposed surfaces of bone are connected by an intervening layer of fibro-cartilage of variable thickness. (3.) Where a greater amount of movement is necessary, the articular surfaces of the bones are coated with cartilage, and layers or bundles of fibrous tissue—*i.e.*, ligaments—pass from one bone to the other so as to surround the articular surfaces, while the joint is further provided with a synovial membrane. In the most complete and perfect of the joints we find also inter-articular fibro-cartilage, either inserted between the cartilage-covered surfaces of the bones or deepening the surface of one of them for the reception of that of the other. Thus then we find in the most perfect and movable joints *bone*, giving firmness; *cartilage*, affording elasticity; *synovial membrane*, supplying a viscid fluid to obviate friction; *fibro-cartilage*, in some cases to lessen friction, in others for the better adaptation of bony surfaces, and occasionally, as in the sterno-clavicular joint, in addition to securing both these ends, the fibro-cartilage affords also a very powerful bond of union between the bones; finally, *ligaments*, to bind the whole together and prevent dislocation.

In the human body there are instances of every possible gradation between the most freely movable and the absolutely immovable articulations; but by the distinctions which have been now pointed out, we are able to classify all joints under three heads—viz., the movable, the yielding, and the immovable.

Every *movable* articulation, or diarthrosis, includes in its construction all the tissues above enumerated, except fibro-cartilage, which occurs only in some of them. The *yielding*, or amphiarthrosis, has no proper synovial capsule or lining, but always a fibro-cartilage and ligaments; and the *immovable*, or synarthrosis, possesses nothing beyond bone, except in some instances a sutural ligament.

We must now consider each of these three species of joints separately.

Synarthrosis or Immovable Joint.—This kind of joining is made use of to unite different bony portions into one solid shaft or case. By this combination increase in size by growth is provided for; the chances and results of injury are diminished; while more complete protection is afforded to the parts which the bones surround. It includes all those articulations in which the bones are in direct, or almost direct, contact, where there is no intervening fibro-cartilage or synovial cavity, where

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periosteum alone passes from one bone to the other, and where movement is also absolutely impossible.

In those bones which are developed in cartilage, cartilage for a time—*i.e.*, until the process of ossification is completed—intervenes and binds together the osseous parts. This is the case in the base of the skull, where the basilar part of the occipital bone joins the body of the sphenoid, and is also the way in which the epiphyses are connected with the shafts of bones. But it is not usual to regard the occipito-sphenoid union, or the connexion of the epiphyses with the shafts of long bones, as joints, seeing that there is only a temporary difference of structure at these joinings, and that they have no relation whatever to movement, but only to growth and development.

The immovable or synarthrodial joints are like the union of the epiphyses and diaphysis of bones in this respect, and therefore, though interesting from the point of view of the construction of a skeleton, yet as having no relation whatever to movement do not fall within the scope of this work.

Amphiarthrosis.—In this form of articulation, where slight movement is required to be combined with great strength and with the means of breaking shocks, the contiguous osseous surfaces are connected together by broad flattened discs of fibro-cartilage bound over by ligamentous fibres. In this manner the bodies of the vertebræ are connected together. In their modes of union these joints somewhat resemble synarthrosis, from which, however, they are distinguished by the invariable presence of fibro-cartilage and by the motion or yielding which occurs at them. It is true that as life advances the connecting structure gradually loses its elasticity, but the joint has but slight tendency to become obliterated by ossification. Sometimes, as in the pubic and sacro-iliac articulations, the connecting fibro-cartilage is split through a greater or less extent, and a synovial-like membrane lines the interspace. In this respect—*i.e.*, from the slight synovial interval in the cartilaginous substance, and from the mobility which is permitted—these joints resemble the diarthrodial. The amount of mobility in the joints of the pelvis is often much increased during pregnancy by the swelling of the symphysial cartilages. Occasionally these joints become obliterated in old age.

After some fractures, such as those of the patella, neck of the femur, and olecranon, the bones become reunited by an intervening substance which allows of movement taking place between the fractured parts: thus a supernumerary or abnormal amphiarthrodial joint may be formed.

Diarthrosis.—This is the most movable class of articulation. It includes the greater number of the joints in the body. It is the kind of connexion which exists between the bones of the extremities, as well as between the extremities and the trunk. It allows of constant motion, as witness the costo-vertebral articulations in their movements of respiration. It is lined by synovial membrane and strengthened more or less by ligaments. In some joints of this class fibro-cartilage occurs in the form of inter-articular discs, but these discs serve no purpose in holding the bones together. Union is effected by bands and layers of ligamentous tissue, by the tendons of muscles, and by atmospheric pressure. Neither the shape of the osseous surfaces, which is the mode of union in the synarthrosis; nor the intervening soft elastic tissue which unites the osseous edges in amphiarthrosis, has any effect in holding the bones of diarthrosis together. There is, in fact, no single instance of a diarthrodial joint in which the separation or falling asunder of the bones is prevented by either of these means, nor is there an instance of such a joint in which the movements are checked by the shape of the osseous surface or by the fibro-cartilages; for either the tension of ligaments, or the apposition of soft parts checks movement before the edges of the osseous surfaces have any influence upon it. The shape of the articular osseous surfaces varies much in different joints, and as a result of this variation the motions of the joints differ, and according to this difference in their movements a classification of joints of this kind is made under four headings:—
1. The gliding joint: *Arthrodia.* 2. The hinge joint: *Ginglymus.* 3. The lateral hinge joint: *Trochoides.* 4. The ball and socket joint: *Enarthrosis.*

Arthrodia is formed by the apposition of two plane or nearly plane cartilage-covered articulatory surfaces. It is the least movable of all the diarthrodial joints, and the movements consist only of a slight gliding of one bone upon the other. A number of small bones are generally united in this manner, and while they allow of a considerable amount of pliability and yielding and even of combined movement, they also provide a security against injury. Such is the case in the tarsus and carpus.

Ginglymus.—In the hinge joints, instead of two nearly plane surfaces there is a convexity presented by one bone and a corresponding concavity by the other. Both articular surfaces are lengthened laterally, and owing either to the processes of bone or to strong lateral bands of ligament motion is allowed only in two directions—viz., forward and backward—*i.e.*, flexion and extension. The most perfect examples of the hinge joint are the elbow and the ankle.

Trochoides is the name given to such joints as that between the odontoid process of the axis and the ring formed by the transverse ligament and the anterior arch of the atlas, and that between the upper extremity of the radius and ulna. The osseous surfaces are one convex and the other concave, the convex being held to the concave by a strong ligament embracing it as at the superior radio-ulnar articulation, or by a fibro-cartilaginous plate as at the inferior radio-ulnar joint. The movement permitted at these joints is of a rotatory character; in one case the rotation is of the convex bone round its own axis and within an osseo-ligamentous ring—*e.g.*, the head of the radius; or the osseo-ligamentous ring rotates round the convex bone as at the atlo-odontoid, and occasionally at the superior radio-ulnar joints. In the inferior radio-ulnar joint either of the bones may rotate round the other; the one being held in constant apposition with the other by means of the triangular fibro-cartilage which corresponds to the radius of the circle of rotation.

Enarthrosis is a joint in which the smooth rounded head of one bone plays within a deep, or upon a shallow, socket in the other. The two are kept in apposition by muscles or atmospheric pressure, assisted by a capsular ligament. They differ from one another according as the socket is shallow or deep. The shoulder and the hip are the best instances of the two kinds respectively. Movement is permitted in the ball and socket joint in all directions; thus we have forward and backward movement—*i.e.*, flexion and extension; movement towards or away from the median plane of the body—*i.e.*, adduction or abduction; a succession of these four angular movements, as when we swing the arm round and round so as to describe a cone, the base of which is formed by the hand and the apex at the shoulder-joint: this is called circumduction.

Further, there is permitted at the ball and socket joints a rotation of the long bone around its own long axis; this is true rotation as distinct from circumduction. Finally, there is a considerable amount of gliding going on during the several angular movements. Thus then all the kinds of movements which are possible at any other joint take place at the ball and socket articulations, and they are therefore by far the most freely movable species of diarthrosis, and consequently of all joints in the body. The degree of motion permitted is regulated, not by the depth of the socket, but by the muscles and the contact of the soft parts of the limb with the trunk, as at the hip and shoulder; or by ligament, as in the case of the ilio-femoral ligament in the erect position.

As there is a gradual transition from the immovable to the movable through the amphiarthrodial or mixed articulations, so there is a gradual transition from or merging of the characters of one species of diarthrosis with those of another. It is sometimes difficult to draw the line between a true hinge joint and an arthrodial; there is great similarity between the true arthrodial and the enarthrodial with a shallow socket, and the characters of the hinge are sometimes combined with those of the ball and socket. Thus in some of the joints with an inter-articular cartilage, such as the temporo-maxillary and the sterno-clavicular, gliding is combined with a hinge motion so intimately as to make it impossible to say that these joints belong strictly to either arthrodia or ginglymus. In the inter-carpal joint the two rows of carpal bones are so adjusted to one another as to resemble a double ball and socket joint with very shallow sockets. The joint between the metacarpal bone of the thumb and the carpus is intermediate between the hinge and ball and socket varieties.

In some situations where a variety of movement is required to be associated with great strength and security, the object is gained by the juxtaposition of two or more joints, each of which allows of a different class of motions. This is the case in the connexion of the head with the spine; at the junction of the hand with the bones of the forearm, where the radio-carpal and inferior radio-ulnar work in unison to produce a combined result; and of the foot with the leg, for while flexion and extension take place at the ankle, lateral movement and slight rotation occur between the astragalus and os calcis.

Occasionally two or more joints combine to increase or add security to the same kind of movement. This associated effect is seen between the radio-carpal, the intercarpal, and the carpo-metacarpal joints; and between the atlas and axis, where the two lateral arthrodial articulations support and steady the atlas while it is revolving round the odontoid process at the lateral hinge joints—viz., the central atlo-axoidean.

This multiplication of joints serves to combine freedom of movement with strength; a necessary provision in certain places, for as a rule the strength of any single joint, and its power of resisting injury, is inversely proportioned to the freedom of mobility. Take, for example, the shoulder and elbow; or the hip-joint and the ankle; or the temporo-maxillary and the joints of the spinal column; in each of these mobility is in inverse proportion to strength and security.

Although similar structures are employed in the construction of all diarthrodial joints, yet the joints vary much in their solidity and extent and direction of movement. These differences depend upon the shape of the articular surfaces of the bones, and upon the direction and length of the fibres of the ligaments connecting them. Indeed the course of the fibres, and the direction in which they pass to their insertion into the bones of the joint, illustrate with tolerable certainty in what manner they regulate and limit the movements of the articulation.

Supernumerary diarthrodial joints are occasionally formed by the non-union of fractures, the fractured ends becoming smooth and rounded off by friction, and surrounded by a ligamentous capsule, the inner surface of which yields a synovial-like fluid. Supplemental diarthrodial joints sometimes result from unreduced dislocations. They are most frequent about the hip and shoulder.

CHAPTER III.

THE ARTICULATIONS OF THE SKULL.

There are only two pairs of movable joints connected with the skull—viz., *the temporo-maxillary* and the *occipito-atlantal.* At the former the condyles of the inferior maxilla move like hinges in the glenoid fossæ of the temporal bones; at the latter the skull, as a whole, moves by means of its occipital condyles in the boat-shaped sockets of the lateral masses of the atlas. These articulations of the skull resemble one another in that each consists of two complete, symmetrical joints, placed one on either side of the median line of the base of the skull. Further, the articular surfaces of each separate joint are oblique with regard to both the vertical and the horizontal plane; thus the condyles of the lower maxilla have their long axis obliquely transverse, being directed backwards and inwards, while the inner ends of the condyles are on a slightly higher plane than the outer; those of the occiput have their long axis oblique in the antero-posterior direction, but with an inclination outwards and backwards, while their inner borders are prolonged to a lower plane than their outer. The sockets in the squamous bone and the atlas are correspondingly oblique both vertically and in their long axis in adaptation to the condyles which they respectively receive.

This bilateral arrangement, or arrangement in pairs of joints, gives great width to the basis of support at the top of the spine upon which the head rests, and upon which its movements take place; it also provides a combination of strength and security with great freedom of movement, which could not possibly have been afforded by a single joint, even of much larger dimensions.

These several joints share both the hinge and arthrodial characters. In each the chief, but not the only movements, are hinge-like, as is shown by the nodding movement of the head and the opening and the closing of the mouth. There is also permitted a certain amount of gliding (more especially at the temporo-maxillary joint), and some oblique rotatory movement of both pairs of condyles within their sockets.

There are, however, the following differences between the temporo-maxillary and the occipito-atlantal articulations, which will be more fully brought out in the subsequent descriptions of these joints: (1) At the former the convex articular surfaces belong to the lower jaw, and the concave sockets to the base of the skull; at the latter the convex articular surface belongs to the base of the skull, and the concave facets to the atlas. (2) At the former the hinge-like movements occur round a transverse axis, which nearly corresponds in direction with the long axis of the condyles of the jaw: at the latter the hinge-like movements take place round a transverse axis, which cuts the long axis of the occipital condyles obliquely. (3) At the former pair of joints there is an inter-articular fibro-cartilage on each side; at the latter there is no such structure.

The Temporo-maxillary Articulation.

Class, Diarthrosis. *Subdivision*, Ginglymo-arthrodia.

The lower jaw is the only bone of the skull which is capable of separate movement—*i.e.*, of movement independent of the rest of the cranium. In man, as in all mammalia, this articulation is formed between the inferior maxilla and the squamous portion of the temporal bone. Perhaps the temporo-maxillary joint, more than any other fragment of the vertebrate skeleton, gives the fullest information respecting the animal to which it belonged. In all mammalia, the *convexity* of the lower jaw is received into the *concavity* of the squamous portion of the temporal bone; whereas, in the three other divisions of the vertebrate kingdom, the inferior maxilla presents a concavity to the convexity of the cranial bone with which it articulates—viz., with the homologue of the human tympanic ring (the os quadratum) in birds, reptiles, and osseous fishes, and with the homologue of the human internal pterygoid plate in cartilaginous fishes. Thus therefore, if we see a temporo-maxillary joint, or even the articular process of the lower jaw, we can tell whether the animal to whom it belonged suckled its young, or had a diaphragm or an epiglottis, or an epidermic exoskeleton in the form of hairs, for if so, the lower jaw has a convex articular surface; or whether it laid eggs and had been without hair, a diaphragm, or an epiglottis, in which case the lower jaw has a concave articular surface.

No physiological reason that I am aware of can be given for this difference of construction; it seems to have no relation to external conditions, or to the circumstances of the animal's existence, but to be due only to the position of the animal in the vertebrate series. For the purposes of life and utility, it appears a matter of indifference whether the articular surface of the lower jaw is convex or concave, for "the bat that flies, but not the swallow; the whale that swims, but not the codfish; the camel that walks the desert, but not the ostrich; the carnivorous lion, seal, and weasel, but not the eagle, penguin, crocodile, and shark, have convex articulations to their lower jaw, and present to them their squamosal bones."

In some of the mammalia the joint is a true hinge; this is the case in the carnivora, and reaches its acme in the badger, in the dry skull of which the lower jaw remains locked in the deep socket of the cranium, without any artificial contrivance, and can be removed only by slipping each half out sideways when the symphysis has been divided. In others of the mammalia—the Ruminants—the articular facets approach more nearly to plane surfaces, and the movements are of the arthrodial nature; hence the extensive lateral movements of the jaw while chewing the cud, and the limited power these animals possess of gaping, which is a movement of the hinge character. But in man, who is an omnivorous animal, there is a combination of these two extreme forms, and thus the human temporo-maxillary joint cannot be classed with either the true ginglymoid or arthrodial joints, but partaking of the movements of each, ought to be called "Ginglymo-arthrodia."

The OSSEOUS PARTS of this joint are the squamous portion of the temporal bone including the glenoid fossa, and the glenoid ridge (*i.e.*, the anterior root of the zygoma, and called also the eminentia articularis), which stands just in front of the fossa; and the condyle of the lower jaw. They are all coated with articular cartilage, which stretches even over the front of the glenoid ridge, for the easy play of the inter-articular fibro-cartilage.

The Squamous portion of the Temporal Bone is situated at the lower lateral region, and extends a little inwards on to the base of the skull. Where the basal joins with the lateral portion of the cranium, there arises from its external surface a flattened branch of bone—the zygoma—which runs first horizontally outwards, and then, twisting upon its own axis, curves horizontally forwards. The zygoma arises by two roots, an anterior and a posterior. The anterior is also inferior, and takes a transverse course along the basal part of the temporal bone: it forms the front boundary of a large fossa, also situated on that part of the squamous bone which extends inwards to form part of the base of the skull: it is covered in the recent state by articular cartilage, and sometimes receives the name of "eminentia articularis." The posterior, also the superior, root arises by two branches; one of these is short, thick, and oblique, commencing in front of the outer end of the Glaserian fissure, and of a plate of bone which separates the glenoid fossa from the auditory canal—viz., the tympanic plate of the temporal bone; the other has a horizontal course above the external auditory meatus, and is continuous behind with the curved ridge, separating the squamous from the mastoid bone. Where the anterior and posterior roots join there is on the outer and lower side a rough tubercle, to which the external lateral ligament of the jaw is attached.

The glenoid fossa is an oval-shaped, deep depression, whose long axis is directed inwards and backwards and a little upwards, and measures rather over one inch; from anterior to posterior edge across the fossa is usually rather less than half an inch. It is divided by a narrow fissure, named the Glaserian fissure, into two nearly equal parts—viz., an anterior and external, which is articular and covered by cartilage; and a posterior and internal portion, which is non-articular, and lodges the deep part of the parotid gland. Although the glenoid fossa is wider transversely than from behind forwards, yet the articular surface for the fibro-cartilage of the joint measures more in an antero-posterior than in the transverse direction, owing to the extent to which the articular surface is continued over the glenoid ridge, and to the fact that all the parts of the glenoid fossa behind the Glaserian fissure are non-articular. This is to allow of the considerable forward and backward gliding movement which goes on in the temporo-maxillary joint.

Situated immediately behind the fossa from without inwards, are the external auditory meatus, the styloid process with its vaginal sheath, and the posterior lacerated foramen. To its inner side from before backwards, are the opening of the carotid canal, the processus cochleariformis, and opening for the Eustachian tube, and the spine of the great wing of the sphenoid; in front is the anterior root of the zygoma, and externally and above the posterior root.

The Inferior Maxillary Bone.—Each of the condyles of the lower jaw is supported upon a narrow neck surmounting the posterior border of the ascending ramus. The *neck* is flattened from before backwards; smooth and convex behind; concave in front where it gives insertion to the external pterygoid muscle. It is strengthened by ridges which descend from the sides of the condyle; that from the outer end of the condyle is continued on so as to form the upper border of the ramus at the sigmoid notch, that from the inner end of the condyle descends on to the inner surface of the ramus above the inferior dental foramen. The neck is somewhat curved so as to make the condyle look a little forwards. The *condyle* is elongated in the transverse direction, is convex both from side to side, and from before backwards, and is obliquely inclined, so that the long axes of the two condyles if prolonged would meet at the front margin of the foramen magnum and form an angle of from 155° to 160°. This obliquity facilitates the so-called rotatory movement of the jaw. The condyles are covered with cartilage, which is thickest over the front aspect, and is continued lower down behind than in front.

Anterior to the neck is the sigmoid notch, and in front of the notch and prolonged upwards from the anterior border of the ramus is a flattened triangular process—the coronoid—which gives insertion to the temporal muscle.

THE LIGAMENTS.—Uniting the bones of this articulation is a capsular ligament. Within the capsule and between the osseous articular surfaces is a disc or plate of fibro-cartilage. Also in connexion with this joint the stylo-maxillary ligament must be described.

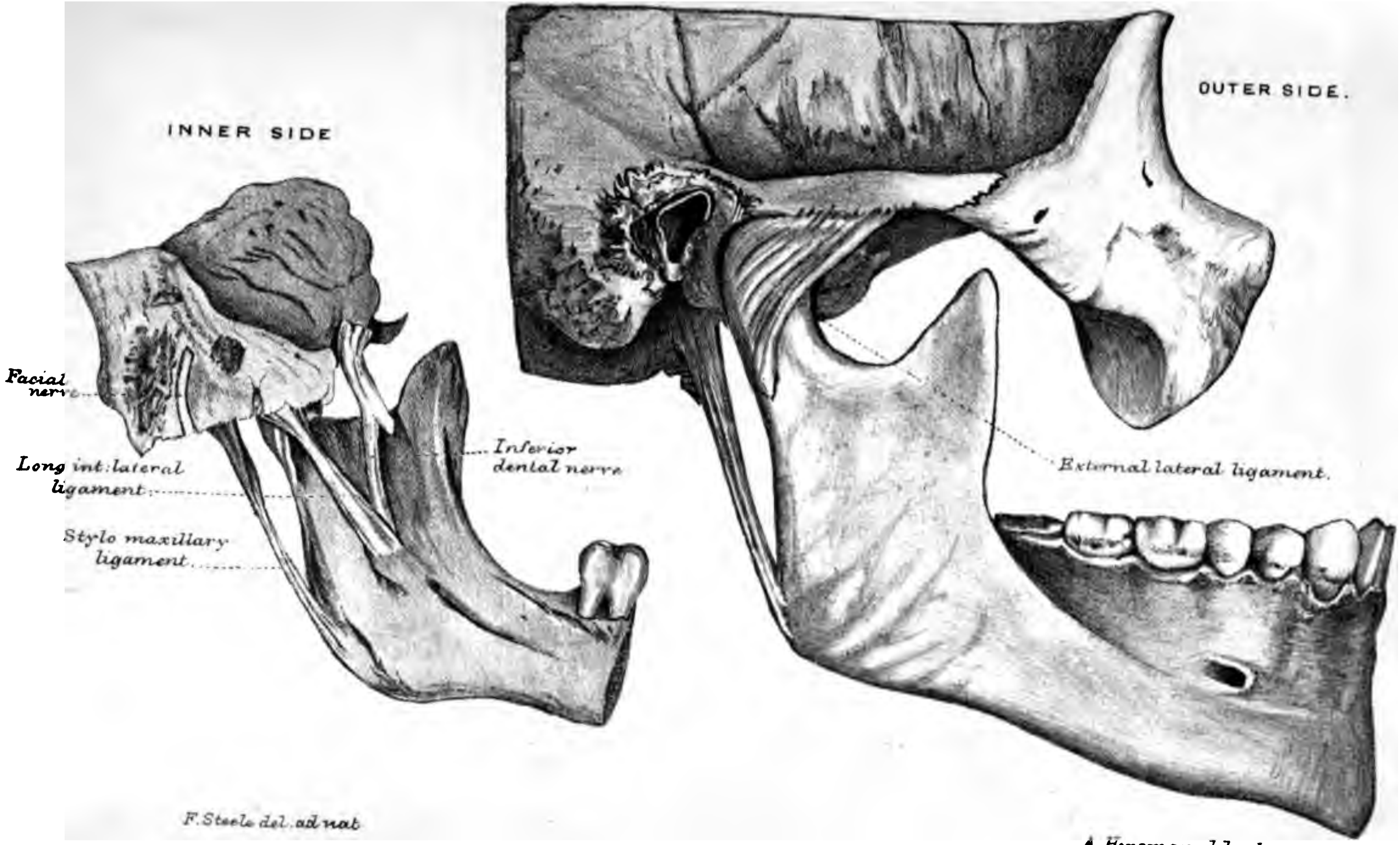
The Capsular Ligament.—Everywhere passing between the temporal and inferior maxillary bones near the margins of their articular surfaces are numerous scattered ligamentous fibres which serve to strengthen the synovial sacs, and to form a nearly complete capsule for the articulation. In some places these fibres are much thicker than at others, and hence it is usual to describe the capsule as composed of four parts or ligaments. It must be understood, however, that these four parts are continuous with one another around the articulation.

1. *The Anterior Ligament.*—The anterior portion of the capsule is so thin and its fibres so scattered, as scarcely to deserve a special notice. It consists of a few stray fibres, connected with the anterior margin of the fibro-cartilage, which are attached above to the forepart of the anterior root of the zygoma (eminentia articularis), and below to the anterior edge of the condyle. Some of the fibres of the external pterygoid muscles pass between these ligamentous fibres to be inserted into the anterior margin of the fibro-cartilage. This part of the capsule retains the fibro-cartilage towards the forepart of the glenoid fossa, so that even when the mouth is closed the thin central part of the cartilage is on the eminentia articularis, and the thick posterior edge is at the bottom of the fossa.

2. *The Posterior Ligament.*—The posterior portion of the capsule is attached above to the hinder edge of the articular part of the glenoid fossa—*i.e.*, just in front of the Glaserian fissure, and is inserted into the back of the jaw just below its neck. It checks forward movement of the jaw.

3. *The External Lateral Ligament.*—The external portion of the capsule is the strongest of all, and connects the posterior portion with the stray fibres of the anterior part. It is broader above than below, being attached to the lower edge of the zygoma in nearly its whole length, as well as to the tubercle at the point where the two roots of the zygoma meet. It is inclined downwards and backwards to be inserted into the ridge on the outer side of the neck of the condyle. Its fibres diminish both in obliquity and strength from before backwards, those arising from the tubercle of the zygoma being very short and nearly straight.

By the greater number of its fibres this ligament prevents the condyle of the jaw being carried backwards, so as to press against the tympanic plate of the petrous bone. By its short posterior fibres it checks the forward gliding of the condyle in opening the mouth. It braces the jaw firmly up to the base of the skull, by fixing the neck of the condyle; yet it also allows



F. Steele del. ad nat

West, Newman & Co. lith.

A. Hensman del. ad nat

of the condyle advancing and receding under cover of it, as in opening and closing the mouth.

The Short Internal Lateral Ligaments.—There are two structures named internal lateral ligaments, the long and the short. One of them, *the long*, is distinct and independent of the capsule, and will be further on described. They have by some been considered as a single ligament, which divides immediately beyond its origin into two parts. The internal portion of the capsule, or the short internal lateral ligament, has above a broad attachment to the outer part of the spine of the sphenoid bone and to the internal edge of the glenoid fossa, and below has a narrow insertion into the ridge on the inner side of the neck of the condyle. Behind it is continuous with the posterior portion, and in front are the scattered fibres of the anterior portion of the capsule, and the insertion of the external pterygoid muscle. It is separated from the long internal lateral ligament which is on its inner side by fatty and cellular tissue. It consists of well-defined ligamentous fibres which assist the external lateral ligament in checking both the forward and backward gliding movements during the opening and shutting of the mouth. Like the external ligament it fixes the neck of the jaw, into which both are inserted on nearly the same level, during the gliding movements of the condyle; and the condyle plays forwards and backwards between the two ligaments which prevent its lateral displacement, and limit the extent of anterior and posterior gliding.

The Inter-articular Fibro-cartilage is constantly met with in the mammalian, but not in either of the other vertebrate classes. Its shape is adapted both to the condyle of the jaw, and to the articular portion of the squamous bone. It is thinner at its centre than at its circumference, and is thicker behind, where it covers the thin bone at the bottom of the glenoid cavity which separates it from the dura mater, than in front where it projects on to the articular eminence. Its inferior surface is concave in adaptation to the convexity of the condyle, and its superior surface is concavo-convex from before backwards, and is in contact with the articular surface of the temporal bone, which is convexo-concave from before backwards. As seen from above it is oval in shape.

Occasionally it is perforated at its centre, otherwise it completely divides the joint into two distinct cavities, an upper and a lower, each having its own special synovial membrane. It is connected at its circumference by loose fibro-cellular tissue with the lateral and posterior portions of the capsular ligament; in front the slender scattered capsular fibres are immediately attached to the margin of the cartilage, and some of the fibres of the external pterygoid are inserted into it as well as into the anterior fibres of the capsule.

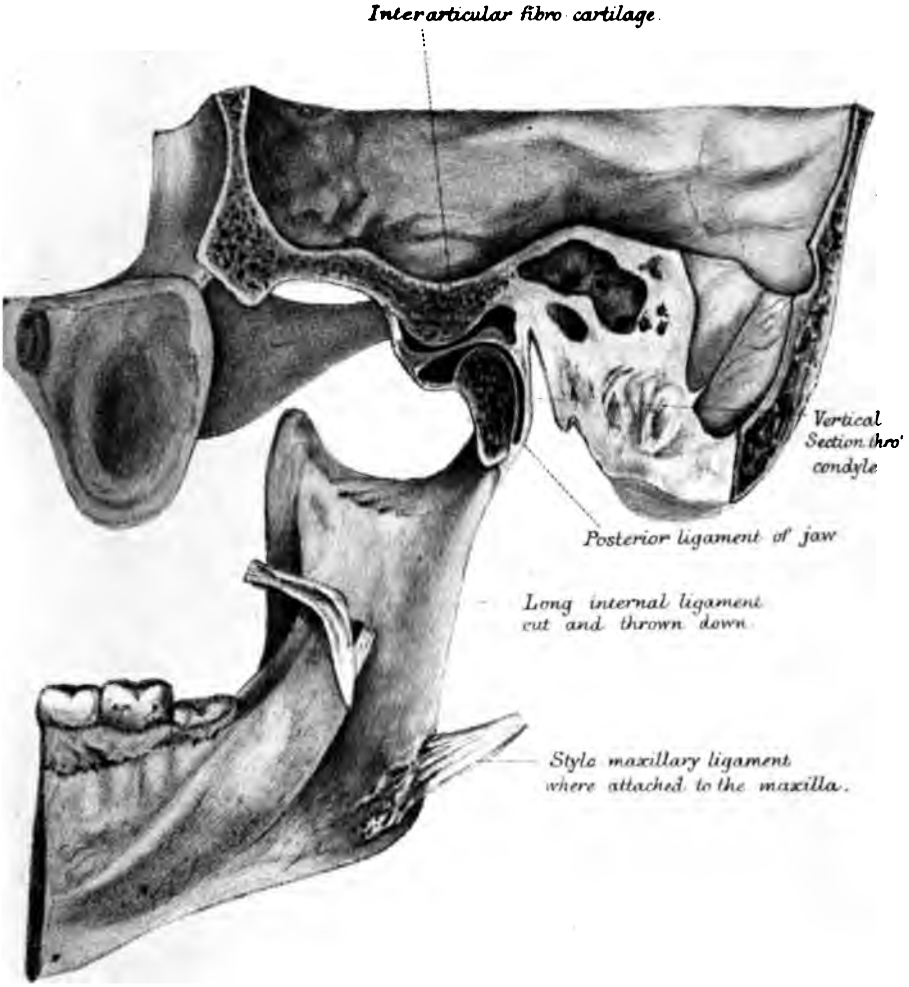
This inter-articular cartilage acts as an elastic buffer between the bones, and intercepts the pressure and breaks the jars which necessarily occur during the movements of mastication; by making good any want of adaptation of the articular surfaces to one another it tends to prevent luxation; and thirdly, like the inter-articular cartilage at the sterno-clavicular joint, it takes an important part in the movements of the articulation, accompanying the condyle in the forward and backward gliding movements, and affording a concave surface for the condyle to turn upon in the hinge-like movements.

The Synovial Membranes.—The articular surface of the temporal bone is larger than the condyle of the jaw, and as a consequence the upper cavity of the joint is larger than the lower. In accordance with this difference the superior synovial sac is larger than the lower. It is also necessarily looser, owing to the backward and forward movements of the fibro-cartilage with the condyle. The sacs are strengthened by the anterior fibres of the capsule, by the lateral and posterior portions of the capsule, and by the fibro-cellular tissue which connects these portions with the fibro-cartilage.

The Long Internal Lateral Ligament is a thin, loose, and elongated slip situated at some distance from the joint. It extends from the spinous process of the sphenoid and the contiguous part of the temporal bones downwards, outwards, and a little forwards, to be inserted into the forepart of the tip of the inferior dental foramen. It covers the hinder—*i.e.*, the upper part of the mylo-hyoid groove as it passes forwards and downwards to its insertion. Its origin is a little internal to and behind, but close to the superior attachment of the short internal lateral ligament, and is concealed by the origin of the external pterygoid muscle. It has no immediate connexion whatever with the articulation, being separated from it by a considerable interval along which pass the external pterygoid muscle to its insertion, the inferior dental nerve,

PLATE II.

ANTERO - POSTERIOR VERTICAL SECTION THROUGH JAW.


Interarticular fibro cartilage.
Vertical Section thro' condyle
Posterior ligament of jaw
Long internal ligament cut and thrown down.
Stylo maxillary ligament where attached to the maxilla.

A. Hensman del. ad nat
West, Newman & Co. chrom. lith

and the internal maxillary artery and vein with their middle meningeal and inferior dental branches. The middle meningeal is conducted upwards to the foramen spinosum, and the inferior dental downwards to the dental canal along the side of the ligament. The influence of this ligament on the movements of the joints must be very slight, and can only act in assisting to limit the opening of the mouth.

The Stylo-maxillary Ligament.—The stylo-maxillary or suspensory ligament is in truth a process of the deep cervical fascia, but is generally enumerated as one of the ligaments of the temporo-maxillary joint. It extends from the styloid process of the temporal bone to the angle of the jaw, where it is attached along a somewhat extended surface of bone between the masseter and internal pterygoid muscles. It separates the parotid from the submaxillary glands, and gives origin to some of the fibres of the stylo-glossus muscle; indeed, it is of more importance as a surface of attachment for this muscle than as a means of connexion between the temporal bone and the lower jaw.

ARTERIES.—Sometimes articular arterial twigs are given off from (1) the branches to the parotid gland from the posterior auricular artery; (2) from the tympanic branch of internal maxillary, as it passes up between the articulation to enter the Glaserian fissure; and (3) from the inferior or ascending palatine branch of facial, by the twigs which run along the Eustachian tube.

The temporal artery gives branches off directly to the articulation.

The middle meningeal, which is conducted along internal lateral ligament.

Ascending pharyngeal, by branches to Eustachian tube.

NERVES.—The masseteric branch of the inferior maxillary division of the fifth gives a filament or two to the joint.

Auriculo-temporal trunk of inferior maxillary nerve gives articular branches directly from itself, or twigs from its parotid or auricular branches, or from the branches to the meatus auditorius.

THE MUSCLES.—Of the muscles connected with the temporal and inferior maxillary bones some have no action whatever upon the movements of the temporo-maxillary articulation. Such is the case with the chief part of the genio-hyo-glossus attached to the superior genial tubercle of the symphysis; the superior constrictor of the pharynx, which arises in part from the back of the mylo-hyoid ridge; the small mylo-glossus (of Wood), which usually springs from near the angle of the jaw; the buccinator, which arises partly from the back part of the alveolar process of the lower jaw; the depressor anguli oris, the depressor labii inferioris, and the levator menti, all of which are attached to the outer surface of the horizontal ramus; the levator palati, which springs in part from the petrous bone in front of the orifice of the carotid canal; the tensor palati, part of whose origin is from the edge of the tympanic plate of the temporal; the stylo-hyoid, stylo-glossus, and stylo-pharyngeus. None of these muscles produce any effect whatever upon the movements of this joint.

Of the rest—those which move the jaw on the head—may be grouped as protractors, retractors, elevators, and depressors of the lower jaw; whilst those which move the head on the jaw, when the chin is kept fixed, are the same muscles which extend and flex the head at the occipito-atlantal articulation.

The *Elevators of the Lower Jaw* are—the temporal, which acts upon the coronoid process; the masseter, which is inserted into the outer side of the ascending ramus and of the angle; and the internal pterygoid, which is attached to the angle on the deep aspect of the bone. These muscles usually act together, and by bringing the lower teeth forcibly into contact with the upper are the great powers of mastication—*i.e.*, for grinding the food. As they have to resist the force and overcome the hardness of the substances which require to be triturated before being swallowed, they are necessarily muscles of large size and of great strength.

The *Depressors of the Lower Jaw* are much smaller in size and of less strength than the elevators. The jaw almost falls by its own weight, and these muscles have therefore to overcome little or no force in moving it downwards. They are the digastricus, which pulls upon the symphysis of the jaw at the digastric fossa; the mylo-hyoid, attached to the ridge of the same name; the platysma, inserted into the outer side of the lower jaw from symphysis to masseter; the inferior fibres of the genio-hyo-glossus; and the genio-hyoid, inserted into the lower tubercle on the deep surface of the symphysis. Each of these muscles serves other purposes besides that of depressing the lower jaw; the genio-hyoid, mylo-hyoid, and the anterior belly of the digastricus (when acting apart from the posterior belly) all draw the hyoid bone upwards and forwards; the posterior belly of the digastricus (acting without the anterior belly) draws the hyoid upwards and backwards; and when both bellies act together and the lower jaw is fixed, their combined effect is to elevate the hyoid bone. Probably their action on the hyoid bone should be regarded as the chief use of these muscles, but whether or no their connexion with that bone shows, that in order to depress the lower jaw, their action must be associated with that of the muscles which hold down the hyoid itself—*i.e.*, of the sterno-hyoid, omo-hyoid, and the sterno-thyroid with its continuation the thyro-hyoid.

The Protractors of the Lower Jaw.—The external pterygoid is the chief protractor. It is inserted into the forepart of the neck of the condyle of the lower jaw, and into the margin of the inter-articular fibro-cartilage. All the fibres of the internal and external pterygoids, and many of the fibres of the masseter, arise in front of their insertion, and thus have to pass backwards to their attachment (the pterygoids also incline outwards, and the masseter slightly inwards) to the inferior maxilla. The external pterygoid has the great bulk of its fibres so horizontal that they have no effect in elevating the jaw; the internal pterygoid and the masseter being more obliquely directed can elevate as well as protract. In most people, when the jaws are closed, the lower incisor teeth are behind the upper; but when the pterygoids on both sides of the head act simultaneously, they so far protract the lower jaw as to allow of the lower incisors being advanced beyond the upper. In simply opening the mouth the external pterygoids are associated with the depressor muscles, and come into play to draw the condyles slightly forwards. Usually the muscles of one side only act at once, and alternate with those of the opposite side; in this way the teeth are moved away from the side on which the muscles are acting, and thus is produced the grinding and chewing movements of the molar teeth. In these movements the external pterygoid is associated with the internal pterygoid (which assists protraction), as well as with the other elevators of the jaw.

The Retractor of the Lower Jaw.—Only the temporal muscle can retract the jaw, for it is the only muscle of mastication which has any fibres directed forwards to their insertion. All the fibres of the temporal muscle converge and terminate in a strong tendon, which is inserted into the coronoid process. This process serves as a lever for the more forcible action of this powerful muscle.

Certain muscles can be made to move the head upon the condyles of the lower jaw when the jaw is kept fixed. They are the same which produce the corresponding movements at the occipito-cervical articulation. The posterior recti, the trapezius, the splenius capitis, the trachelo-mastoid and complexus, all assist in extending the head on the neck, and therefore to open the mouth by tilting back the head—*i.e.*, by rotating it upon the maxillary condyles, as well as on the facets of the atlas. In the same way the short anterior recti muscles and the sterno-mastoid bring the head forward and thereby close the mouth. The action of these muscles on the occipito-cervical union will be discussed more fully in the next section; here it is sufficient to enumerate them *as the muscles other than those of mastication, which can open and close the mouth when the lower jaw is kept fixed.*

THE MOVEMENTS.—As man is omnivorous, his temporo-maxillary joint is not only intermediate in construction between the carnivorous badger and the cud-chewing ruminants, but is capable of movement in more various directions than either of them, because the substances taken as food by him require different actions for their complete trituration and mastication.

When the jaw is depressed, whether for eating, or speaking, or yawning, &c., the condyles rotate on a transverse axis, the fibro-cartilages with the condyles glide forward, the angles of the jaw are thrown backwards, and the coronoid processes are depressed and tilted forwards; the external lateral ligament, especially, is rendered tense, and the stylo-maxillary ligament is relaxed. When the mouth is closed, precisely the reverse conditions to these hold good.

Thus (1) the chief movement of the temporo-maxillary joint is of a ginglymoid or hinge character, accompanied by slight gliding; (2) there is also permitted a horizontal gliding in an antero-posterior direction, whereby the lower incisors are thrust forwards and drawn backwards, as when we bite with the front teeth. In these two sets of movements the joints on the two sides are similarly and simultaneously engaged.

(3) There is further a grinding or chewing movement, whereby the jaw is pulled obliquely from side to side: this combination of lateral shifting with rotation is produced chiefly by the external pterygoids acting alternately on the two sides; it consists of a gliding of the articular surfaces on one another; but the two joints do not act similarly at the same instant, for while one condyle and its fibro-cartilage is gliding forwards and inwards, and rotating but slightly, the other is revolving to a greater extent round the vertical axis drawn through the outer part of its neck, and gliding but slightly backwards and inwards.

As far as concerns the horizontal gliding movements, this articulation belongs to the class Arthrodia. Had there been no more gliding permitted than that which accompanies the opening and closing of the mouth, it would have been as strictly a hinge joint as the knee, at which a considerable amount of gliding accompanies flexion and extension. But inasmuch as some of the gliding movements occur independently of any hinge-like motions, the joint is a complex one, and compounded of the two varieties, ginglymus and arthrodia.

The movements which occur in the two divisions of the joint are of different kinds. In the upper the fibro-cartilage, moving on the glenoid fossa and eminentia articularis, glides forwards and backwards as in protraction and retraction; or obliquely from side to side as in grinding and chewing. In the lower division the condyle moves against the under surface of the fibro-cartilage, rotates on its transverse axis as in opening or shutting the mouth, or turns on the vertical axis of its neck as in grinding and chewing. Movements in the two divisions of the joint sometimes occur simultaneously in both joints. Thus, in opening the mouth the condyle turns like a hinge in the lower compartment, and at the same time the fibro-cartilage, together with the condyle, moves forwards so as to rise upon the eminentia articularis. In this movement the fibro-cartilage extends as far as the anterior edge of the glenoid ridge, which is coated with articular cartilage to receive it; at the same time the fibro-cartilage presents a concave surface for the condyle of the jaw; but the condyle itself never reaches quite so far as the summit of the glenoid ridge, being checked by the fibres of the lateral and posterior ligaments. In shutting the mouth, the condyle *revolves* back again, and the fibro-cartilage *glides* back again, taking the condyle with it. By this combination of hinge and gliding action, a greater range of movement of the lower teeth is secured by the same expenditure of muscular power, while a tearing as well as a cutting action is given to the incisor teeth by their being drawn backwards at the same time that they are closed upon the upper jaw. Again, in the chewing and grinding—*i.e.*, the oblique rotatory—movement whilst the condyle rotates round the vertical axis of its neck, and moves against the fibro-cartilage, the fibro-cartilage itself glides obliquely forwards and inwards on one side, and obliquely backwards and inwards on the other. If the symphysis be simply moved towards one side and back again (and not from side to side as in grinding), the condyle of that side moves round the perpendicular axis of its neck, and the opposite condyle glides forwards and inwards upon the glenoid ridge. But in the ordinary grinding movement one condyle advances and the other recedes, and then recedes whilst the other advances, and so on; slight rotation taking place in each joint meanwhile. The jaw is drawn inwards by the pterygoids of one side, and outwards or straight again by the pterygoids of the opposite side. The deformity which follows fracture of the jaw, when the fragments are made to overlap by approaching the middle line illustrates the action of pterygoids on the fragment of their own side. The movements of protrusion and retraction—*i.e.*, of forward and backward gliding—are confined almost entirely to the upper compartment. This is owing to the more limited size of the inferior synovial cavity, to the closer connexion of the fibro-cartilage to the condyle than to the glenoid fossa, and to the insertion of some of the fibres of the external pterygoid into the margin of the cartilage, whilst the rest are attached to the front of the neck of the condyle. Thus the same muscle which protrudes the jaw drags forwards at the same instant the fibro-cartilage which is closely connected with it.

It has been stated above that the head can be made to move on the condyles of the inferior maxilla if the chin be held steady. Anatomists are quite silent with regard to, if indeed they have not quite overlooked, this movement, and though it is not of any great importance in the animal economy, it is a feature of interest and worthy of being pointed out; besides, it is occasionally employed, as when the head is suddenly bobbed forwards to give greater force to the masticatory muscles, as in cracking a nut for instance. It may be illustrated by simply fixing the chin in the hand, and then throwing the head back as in looking up to the ceiling; or after opening wide the mouth, closing it, by dropping the head forwards and downwards towards the lower jaw instead of raising the lower jaw towards the upper. In these movements the mouth is opened and closed, but the jaw does not move, and the chin is fixed and supported by the palm of the hand. Under these circumstances the head is resting upon two columns instead of one—viz., (*a*) the spine, and (*b*) the lower jaw supported by the forearm; and it moves on two pairs of ginglymo-arthrodial joints at the same time—viz., the occipito-atlantal and the temporo-maxillary. Two sets of effects are thus produced, for whilst the head is extended or flexed on the spinal column, the mouth, by the same muscles and movements, is respectively opened and closed.

CHAPTER IV.

THE LIGAMENTS AND JOINTS CONNECTING THE HEAD WITH THE SPINAL COLUMN.

In considering the mode in which the head is united to the spine, it is impossible to avoid taking into account the union of the axis with the atlas, not only because the *atlas with the head* rotates upon the axis, but also because the ligament whereby these rotatory movements are rendered secure is a part of the apparatus between the axis and atlas; and further and especially, because the ligaments which check rotation, as well as other very strong ligaments, pass between the axis and occiput, and so provide for the security of the union in a manner in which the ligaments extending from the atlas to the occiput alone could not do.

Moreover, the characters of the atlas, which are all modified to allow of the requisite movements of the head upon it, and of it together with the head upon the axis, exclude it from the general description of the ligaments and joints connecting the several other vertebræ together.

In the following description, the articulations between the occiput and atlas with their ligaments will be first described; then those between the atlas and axis; and finally, the ligaments which extend between the axis and occiput.

The articulations between occiput and atlas are imperfect hinge joints, and those between the lateral masses of the atlas and axis are arthrodial joints; but in addition there is between the anterior portion of the atlas and the odontoid process a lateral ginglymoid joint, which is completed by the transverse portion of the crucial ligament.

The ligaments passing between the atlas and axis, and those connecting the atlas and occiput, are mediate and immediate. The capsular ligaments are immediate—*i.e.*, they hold together parts of the bone which are in contact with one another; the anterior and posterior ligaments are mediate—*i.e.*, they pass between bony parts which are not in contact. Further, the ligaments which connect the atlas and occiput, and those which connect the atlas and axis, are for the most part external to the spinal canal; certainly, with the exception of the transverse ligament, they can be examined without dividing the bones or opening the canal, although it must be admitted that the capsular ligaments of each set of joints, to be completely viewed, must also be seen from within.

On the other hand, the ligaments which most strongly connect the head to the spine, and which serve to retain it in position during the rotatory and nodding movements, pass from the axis and other cervical vertebræ to the occiput, are all contained within the spinal canal, and can only be examined or dissected after laying open the canal. To do this the arch of the axis, the posterior arch of the atlas, and the portion of the occipital bone which bounds the foramen magnum posteriorly, as well as the tube of dura mater and the medulla, and upper part of the spinal cord, must all be taken away.

The Articulations between the Atlas and Occipital Bone.

Class, Diarthrosis. *Subdivision*, Ginglymo-arthrodia.

THE OCCIPITAL BONE.—It is through this bone, which is situated at the lower and back part of the cranium, which is fused with the sphenoid into one mass, and is locked together by means of deep serrations or rough edges with the parietal and temporal bones, that the whole weight of the skull is borne and transmitted to the spine.

The general form of the occiput is rhomboidal or lozenge-shaped, with a large oval hole in its anterior part, which forms the communication between the cranium and spinal canal, and is called the foramen magnum. It is with the ring of bone which surrounds the foramen magnum that we are now concerned; but it is more especially with the lateral segments of the ring—*i.e.*, the *condylar portions* of the occiput, on which the articulating facets or condyles are situated, that we have most to do. The *tabular* portion of the bone which is behind the foramen, and the *basilar* portion which is in front of it, also afford attachment to occipito-atlantal ligaments, and the basilar portion to occipito-axoidean ligaments as well.

The condyles or articulating processes are elliptical in shape, varying from a little less to something more than an inch in length, and half an inch in breadth, and are three-fourths of an inch apart at their anterior extremities. Situated, one on each side, on the external surface of the occiput, close to the margin of the foramen magnum at its antero-lateral portion, they have their long axes directed from behind forwards and inwards; and they converge in front to the extent of half an inch, the posterior extremities being one and a quarter inch apart. They are convex from side to side, as well as from before backwards, and are often marked about their middle in the dry bone by an obliquely transverse groove. A line drawn between these grooves corresponds pretty nearly with the axis round which the hinge-like, nodding movements occur; is as nearly as possible the mid-line between vertical planes through the occipital protuberance and the incisor teeth; and through it the line of gravity in the erect position falls.

Besides their doubly convex contour and their obliquely antero-posterior axes, the condyles are far from being parts of a horizontal plane, as they are considerably everted, so as to look outwards as well as downwards. Thus while their outer margins pass gradually into the bone beyond, their inner edges are prolonged some distance downwards, and in this manner serve to deepen to a very marked degree the lateral portions of the ring of the foramen magnum. Here the ring presents a rough and uneven surface on each side instead of a mere bony edge, to which the strong odontoid or cheek ligaments are attached, and on which the inner opening of the anterior condyloid foramen is seen. The articular surfaces of the two condyles, owing to their shape, inclination, and direction, may be regarded as parts of one and the same sphere, with an interval between them, which play in corresponding distant parts of a socket formed by the atlas.

If the bone surrounding the condyles be carefully observed, it will be noticed that there is a deep fossa and a foramen—the posterior condyloid fossa and foramen—behind. This, by making room for the cups of the atlas during extension of the head on the spine, allows of freer movement in this direction than could otherwise have been possible. The bone over a large area in this situation, where not actually perforated, is very thin and papery. Again in front, and somewhat to the outer side of the condyle, there is another large foramen, the anterior condyloid; while the mass of bone vertically and immediately above the condyle is always perforated obliquely by the anterior, and frequently by an extension forwards and upwards of the posterior condyloid foramen. To counteract the weakening effects of such deficiencies of bone in a situation through which so much weight as that of the skull and its contents (to say nothing of the extraordinary burdens which are often placed upon the head) has to be transmitted, and at which very frequent movements occur, we find on the outer surface of the occipital bone, between the weakened points, three strong bony ridges passing in different directions from each condyle. One is directed forwards along the side of the foramen magnum, and meets its fellow of the opposite side in the middle line at the pharyngeal ridge or spine on the basilar process; another curves backwards along the foramen, and joins the fellow of the opposite side at the lower end of the occipital crest; whilst the third is the strong jugular or transverse process which extends outwards to unite with the mastoid and petrous portions of the temporal bone on either side. Each condyle may therefore be said to have three strong ribs of bone converging to it from different sides, along which the weight which has to be borne by the condyles is conducted to it. These ribs are so situated as to be in the lines of the chief pressure; thus the anterior rib runs backwards from the basilar process, and bears the strain of the front portion of the skull; the lateral rib bears that of the side of the skull, transmitted through the temporal bone; and the posterior receives the pressure of the back and vault of the head, transmitted in part along the crest of the occiput. In connexion with this last rib it is worth noticing that the tabular portion of the occipital bone is everywhere thin enough to transmit light, excepting (1) along the median line between the upper border of the bone and the foramen magnum; (2) along a transverse but somewhat curved line, which crosses the former at the occipital protuberance, and extends between the lateral angles of the bone; (3) along the margin of the bone, and more especially the portion of it above and between the lateral angles. Now it is along these dense parts of the occiput that the pressure of the parietal bones, the weight of the posterior lobes of the cerebrum, and the drag of the tentorium cerebelli tell; and these forces are transmitted from them partly along the occipital crest, to be divided at the foramen magnum between the posterior ribs of the two condyles; and partly along the inferior curved lines and the lower third of the lateral borders of the occiput to the jugular process—*i.e.*, to the lateral rib of the condyle on each side.

Further, the mechanism of the articulation of the skull with the spine cannot be thoroughly understood nor fully appreciated until the entire skull is looked at with reference to it. It is then seen that, in the erect position with the orbits directed ever so little upwards, the condyles are on a slightly but clearly lower level than the hard palate; and that the base of the skull proper—*i.e.*, of the cranium—formed by the basilar portion of the occipital, the body and wings of the sphenoid, and the ethmoid—ascends rapidly and considerably from the foramen magnum forwards. The weight of the anterior and middle lobes of the brain is therefore borne upon a sloping plane whose direction is downwards and backwards to the condyles. Thus the construction of the anterior portion of the base of the cranium, as well as the position of the condyles themselves, dispose the head to balance on the condyles.

Immediately in front of the jugular process and a little to the outer side of the condyle is the jugular foramen, through which the jugular sinus passes into the internal jugular vein, and the eighth cranial nerve escapes. These structures are therefore very close to the occipito-atlantal joint.

Looked at from the *inner surface*, the foramen magnum appears larger than when seen from outside, owing to the bevelling off of its margin behind. Over the situation of the condyles there is a considerable heaping up of bone into a ridge or large tubercle. This bony mass is seen tunnelled by the condyloid foramina, and is continued behind into the margin of the foramen magnum; outwards into the base of the jugular process; and in front it is prolonged onwards on each side of the basilar groove on which the medulla rests. It looks like a bridge of bone over the canal for the hypoglossal nerve, the piers of which spring from the three several strong ribs of bone which diverge from the condyle. It serves the purpose of strengthening the condyles, acting indeed like a "flying arch." To the ridges thus prolonged forwards, as well as to the intervening basilar groove, the posterior common vertebral ligaments, the cervico-basilar, and the occipito-axoidean ligaments are attached.

THE ATLAS consists of a ring of bone having a transverse diameter of rather less and an antero-posterior diameter of somewhat more than an inch. Situated at the antero-lateral portion of the ring on either side, on what is called the lateral mass of the atlas, is an elongated elliptical concave articulating fossa, which looks upwards and inwards, and receives the condyles of the occiput. Like the condyles, the long axis of each fossa is directed obliquely forwards and towards the middle line, so that their anterior extremities are about three-quarters of an inch, and their posterior extremities one inch and a quarter apart. Like the condyles, too, they are often marked by an obliquely transverse groove across the middle of their surface, or their lateral margins are notched so as to give the facets a somewhat hourglass-like outline. Receiving as they do the condyles, the long axes of the facets necessarily correspond to those of the condyles; but their inclination from the horizontal is the reverse of that of the condyles; and thus, while the inner borders of the latter are prolonged downwards, the outer lip of the articular facets of the atlas ascend so as to reach a considerably higher plane than any other part of the bone.

Separating the lateral masses in front is the *anterior arch* of the atlas. It is a thick and dense rib of bone, slightly curved from side to side, and forming an arc of about one-fifth of the ring of the atlas. In the median line on its anterior surface is a small tubercle—the anterior tubercle of the atlas—and on each side of the tubercle is a depression or fossa for muscles. On its posterior aspect is a small circular and slightly concave facet for the odontoid process of the axis. This facet extends the whole depth of the arch, and is three-eighths of an inch in diameter. Behind the lateral masses is the *posterior arch*, which forms about two-fifths of the ring of the atlas, and is on the whole slighter and shallower than the anterior. Immediately behind the lateral masses on the upper surface of this arch there is a deep groove, often a complete bony canal, which conducts the vertebral artery from the foramen in the transverse process to the spinal canal. It is this groove, and a somewhat similar one on the under surface of the arch, which makes this portion of the ring so slender and shallow. In the middle line behind the bone is considerably deeper, and projects backwards slightly into a sharp tubercle—called the posterior tubercle of the atlas—which is the only representative of a spinous process in this vertebra.

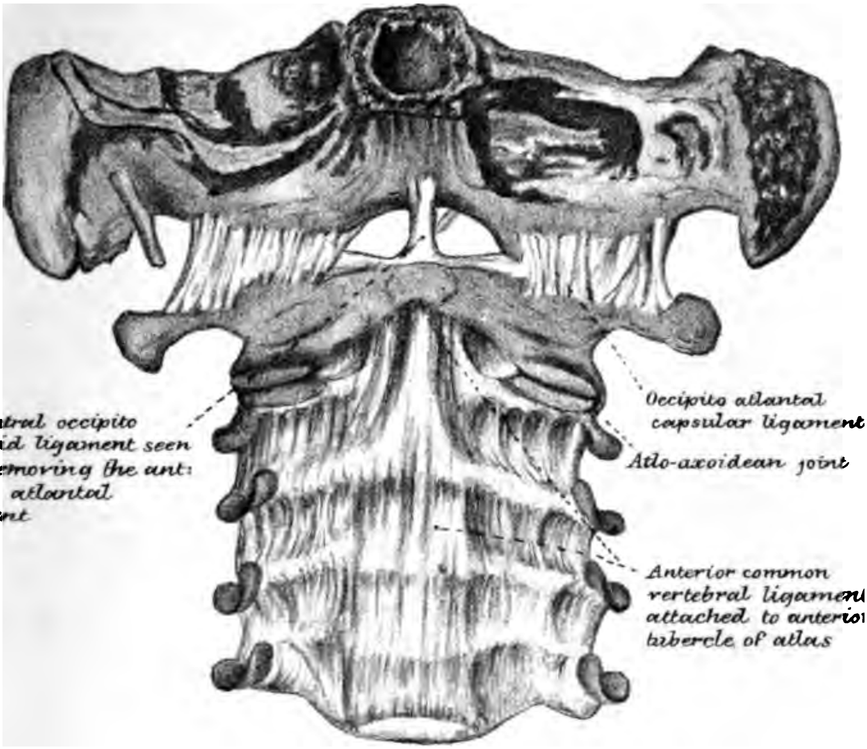
Standing outwards on either side is a long transverse process, which arises, like the corresponding processes of all the other cervical vertebræ, by two roots, and like them is perforated by the foramen for the vertebral artery; one of the roots springs from the front part of the lateral mass, much nearer the upper surface than the lower; the other springs from the point of junction of the lateral mass and the posterior arch, into the borders of which it is indeed continued. Unlike most of the cervical vertebræ, the tip of this process is tuberculated, not bifurcated. The foramen for the vertebral artery is inclined upwards and backwards, and passes by a very gradual and well-rounded border into the groove on the upper surface of the posterior arch.

THE LIGAMENTS.—The ligaments connecting these bones are an anterior and posterior occipito-atlantal and two capsular. The *anterior occipito-atlantal*, when looked at from in front, appears as a broad strong membrane extending from the base of the transverse process on one side to that on the opposite, and considerably thickened in the middle line so as to form what is by some described as a separate ligament, the "central or superficial anterior occipito-atlantal." But in truth much of this broad ligamentous membrane belongs to the capsular ligament of either side, and all that can properly be called anterior occipito-atlantal is the median portion which covers in the triangular space between the front of the foramen magnum and that part of the anterior arch of the atlas between and in front of the superior articular facets. It is about one inch wide, and is composed of densely woven fibres, most of which radiate slightly outwards as they ascend from the front surface and upper margin of the atlas to the basilar border of the foramen magnum; it is continuous laterally with the capsular ligaments, and its fibres are overlapped by others taking an opposite direction, inwards and upwards, which form the anterior part of the capsule of the occipito-atlantal joint. Others, the central fibres, take quite a vertical course as they ascend from the anterior tubercle of the atlas to the pharyngeal tubercle of the basilar bone; they are thicker than the

PLATE III.

LIGAMENTS OF THE UPPER END OF THE SPINAL COLUMN SEEN FROM THE FRONT

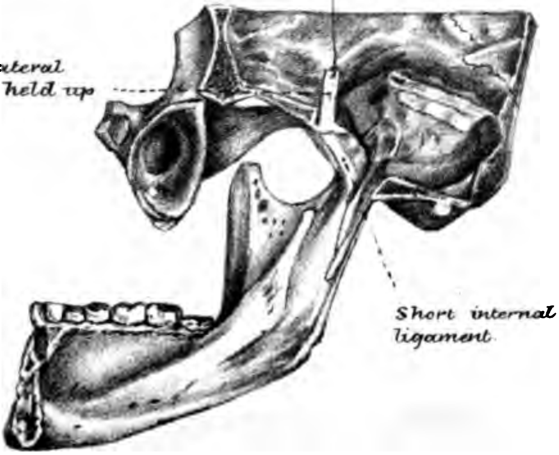
1.


The central occipito odontoid ligament seen after removing the ant: occipito atlantal ligament
Occipito atlantal capsular ligament
Atlo-axoidean joint
Anterior common vertebral ligament attached to anterior tubercle of atlas

F. Steele del. ad. nat.

TEMPORO MAXILLARY JOINT SEEN FROM INNER SIDE

2.


Long internal lateral ligament cut & held up
Short internal lateral ligament.

A. Hensman del. ad. nat.

West Newman

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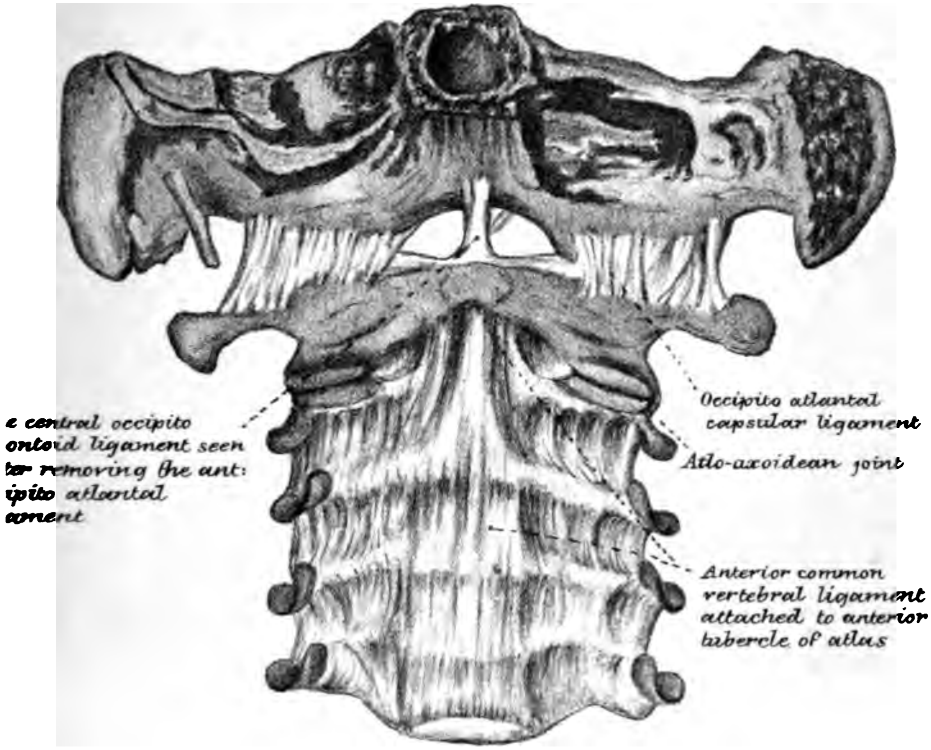
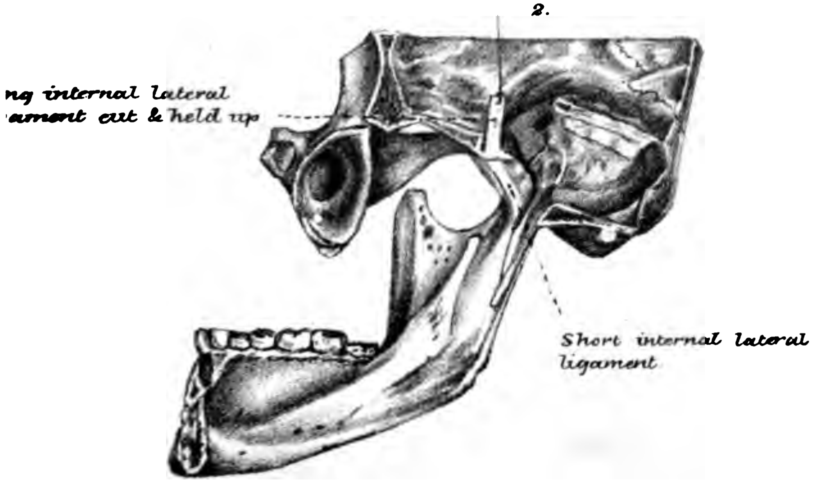


F. Steele del. ad. nat.

TEMPORO MAXILLARY JOINT SEEN FROM INNER SIDE

2.



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more lateral fibres, and are continuous below with the anterior atlo-axoidean ligament, and through it with the anterior common ligament of the vertebral column.

This ligament is of considerable strength, and besides serving to unite the two bones together, acts also to limit extension of the head upon the spine.

The *posterior occipito-atlantal* ligament is much broader than, but not so strong a ligament as, the anterior. It extends from the posterior surface and upper border of the atlas to the posterior margin of the occiput from condyle to condyle. It is somewhat thickened in the middle line by fibres which are attached to the posterior tubercle of the atlas and the lower end of the occipital crest. It is incomplete on each side, to allow of the passage of the vertebral artery into, and of the sub-occipital nerve out of, the canal. It is on its inner surface pretty closely connected with the dura mater. It is not tightly stretched between its bony attachments, and adds little to the security of the connexion between the skull and the spinal column. Nor does it limit in any way the movements of the skull, as it is not even put upon the stretch by the forward or nodding movements of the head.

It corresponds in situation with the ligamenta subflava of the other vertebræ, but it has no elastic tissue, like those ligaments, in its composition.

It serves chiefly the purpose of covering in the spinal canal at a spot where the interval between the bones is as considerable as at the other extremity of the column—viz., where the spine joins the pelvis, *i.e.*, between the fifth lumbar vertebra and the sacrum. At this interval, between occiput and atlas, the knife is introduced in the performance of what is called "pithing" animals.

The *Capsular Ligaments* are very distinct and strong on the outer side as well as in front and behind; but on the inner side the capsule is thin and formed only of short membranous or areolar fibres. The inner margin of the socket of the atlas is very shallow, and the transverse ligament is attached just below it, whilst the check ligaments are inserted into the rough surface above the condyles of the occiput. These structures serve the purpose of strengthening the capsule and of giving support to the synovial membrane of the joint; but the thin capsular fibres cannot add strength to the union of the atlas and occiput, nor are they required to do so, other strong ligaments being sufficient for this purpose. In front, the capsule descends upon the atlas for some distance below the margin of the articular socket, and is attached to the front surface of the lateral mass and to the base of its transverse process; the fibres take an oblique course upwards and inwards, many of them overlying the anterior occipito-atlantal ligament. At the side, the capsule is connected to the atlas just internal to the foramen for the vertebral artery, while further back it is attached to the prominent tubercle at the extremity of the socket which overhangs the groove on the posterior arch for the sub-occipital nerve and vertebral artery. These fibres also take a somewhat oblique course upwards and forwards, and are all attached to the rough outer border of the condyle just above the articular surface.

The capsule is strengthened on the outer side in front by an oblique thick band of fibres, sometimes quite separate and distinct from the rest, which passes upwards and inwards from the upper surface of the transverse process beyond the foramen for the vertebral artery to the inner edge of the foramen lacerum posticum (jugular foramen). This accessory band is described in some works on anatomy as the *lateral occipito-atlantal*, but has been more properly styled by Professor Humphry the *anterior oblique* ligament.

The capsule is also further strengthened on the posterior aspect by another and stronger band of oblique fibres which extends from the overhanging tubercle of the atlantal socket upwards and inwards and backwards to the *tabular* margin of the foramen magnum.

These oblique bands serve to prevent rotation of the head on the atlas, and to draw the head with the atlas round the odontoid process. The anterior band also helps to limit extension, the posterior to check flexion of the head on the spine.

ARTERIES.—These are supplied from the vertebral; occasionally tiny twigs are furnished to this joint, on one or the other side of the body, from the meningeal branches of the ascending pharyngeal which pass through the jugular and anterior condyloid foramina.

NERVES.—The sub-occipital nerve supplies the joint and affords a good illustration of Hilton's law, referred to in

Chapter I.; for besides supplying the posterior recti, the oblique and the complexus muscles, and sometimes also, the skin over the lower part of the occiput, the sub-occipital nerve by its anterior division supplies also the lateral and anterior recti, so that indeed all the muscles which act most directly upon the occipito-atlantal joints are supplied by the same trunk nerve that supplies the joints and the skin over the insertion of the muscles.

MUSCLES.—The muscles related to the occipito-atlantal joints are, for the most part, the same as those related to the atlo-axoidean. They will be examined after the atlo-axoidean joints have been described.

MOVEMENTS.—The occipito-atlantal articulations form one of the pairs of movable joints in connexion with the cranium, and at them the cranium moves upon the spine. Like the temporo-maxillary articulations, they consist of two symmetrical joints placed one on each side of the median line, and have also, like those joints, a doubly oblique direction; but they converge towards the middle line in front, where they are not more than three-quarters of an inch apart, whereas the temporo-maxillary converge towards the middle line behind, and are from two and a quarter to two and a half inches from each other. By the symmetrical and bilateral arrangement of these joints, security and strength is gained at the expense of a very small extent of actual articular surface; the basis of support and the area of action are equal to the width between the most distant borders of the joints, while the interspace is rendered available in the present case for the medulla and its membranes, for the anterior recti muscles which move, and various ligaments which strengthen, the joints; and in the case of the temporo-maxillary joints for the carotid vessels, the third part of the fifth nerves, the Eustachian tubes, the muscles of the palate and the upper part of the pharynx, besides many other important structures.

Almost the only movement which is permitted at these occipito-atlantal joints is flexion. and extension upon a transverse axis; this axis corresponds with a transverse line drawn from the slightly constricted part of one condyle to the corresponding point of the other. In flexion, the forehead and chin drop, and what is called the nodding movement is made; in extension, the chin is thrown up and the forehead recedes.

Thus these joints are ginglymoid or hinge-like in their action. There is, however, also a slight amount of *gliding* movement permitted, and this occurs in two directions. In the one it is *obliquely lateral,* and takes place in the antero-posterior axis of each condyle, so that the anterior extremity of one approaches to a trifling degree towards the median line, and projects beyond the anterior edge of the socket of the atlas, whilst that of the other recedes to a corresponding extent within the edge of the atlas, and away from the middle line; in the other it is *directly lateral,* the outer edge of one condyle sinking a little within the outer edge of the socket of the atlas, and that of the opposite condyle projecting to a corresponding degree. In this latter movement there must be a tilting of the head to one side, and it is even possible that the weight of the skull may be borne almost entirely upon one joint, the articular surfaces of the opposite joint being thrown out of actual contact; this also occurs at the atlo-axoidean joints. The relative condition of the joints on the opposite sides may then not inaptly be compared to the relative state of the hip-joints in the stand-at-ease position. By these gliding movements one side of the head is lowered and the other raised slightly; when the movement is *obliquely lateral or diagonal* the lower side of the head will be a trifle in front of the elevated side. When either the hinge or the gliding movements are carried beyond a certain point, the atlo-axoidean joints and the rest of the cervical vertebræ assist in their production; the hinge and either of the gliding movements may also be combined—*i.e.,* they may take place together; when this is the case, something very like rotation occurs. There is, however, no true rotation round a vertical axis possible between the occiput and atlas.

These various movements are checked partly by the ligaments between the atlas and occiput, and partly by the occipito-axoidean ligaments. Thus flexion is limited almost entirely by these latter, the only occipito-atlantal ligament which assists being the posterior oblique-accessory band of the capsule. Extension, on the other hand, is limited entirely by the anterior occipito-atlantal, and the anterior oblique-accessory band of the capsule; the anterior atlo-axoidean, by fixing the atlas upon the axis, indirectly assists those ligaments by steadying the bone from which they arise and act.

The gliding movements are checked nearly equally by the check ligaments on the interior, and by the outer part of the capsules on the exterior of the articulations.

The Articulations between the Atlas and Axis.

The Lateral Atlo-axoidean Joints.
Class, Diarthrosis. *Subdivision*, Arthrodia.

The Central Atlo-axoidean Joints.
Class, Diarthrosis. *Subdivision*, Trochoides.

The atlas articulates with the axis in the same general manner as the rest of the vertebræ articulate with one another. Thus there are central and lateral joints, each of which is distinct and complete in itself. The lateral joints, however, are situated more towards the front, instead of at the sides of the arch of the bone as is the case in the other vertebræ; the central joint, instead of being single and amphiarthrodial in kind, and therefore wanting in a synovial membrane, is double, and has two synovial sacs, but no intervertebral substance; and lastly, as the body of the atlas is detached from that bone and is consolidated with the body of the axis to form the odontoid process, the central articulations (the atlo-odontoid) occupy a vertical, not a horizontal, plane, so as to permit of a wide range of rotatory movement round a vertical line.

We must look again at the atlas, and then examine the axis, to ascertain how they are adapted to each other in the formation of these articulations.

THE ATLAS presents on each side, upon the under aspect of the lateral mass, a rounded, slightly cupped, articular facet. These facets are not so large as the sockets for the occipital condyles, and as they are placed vertically beneath the middle of these sockets, their posterior borders do not extend quite so far backwards. Like the sockets, they are oblique in direction from side to side, sloping downwards and outwards. As the sockets slope upwards and outwards, it follows that the outer surface of the lateral mass—from which the transverse process springs—is much deeper than the inner surface, and measures nearly three-quarters of an inch, while the inner surface is not much more than one-eighth of an inch in depth. Immediately above the inner surface of each lateral mass is a rough excavated depression the size of a split pea, which lodges a little mass of fat, covered by synovial membrane, and useful in the movements of the occipito-atlantal joints. This depression encroaches considerably upon the central part of the socket for the occipital condyle, and, with a slight indentation of the outer border, gives the socket quite an hour-glass outline. In front of the rough depression is a prominent tubercle for the transverse ligament, and in front of this again a slight recess, which allows of ample room for the play of the bone around the odontoid process, and gives attachment to some strong fibres connecting the odontoid process to the atlas. Behind the articular facets for the axis there is a grooved depression on the posterior arch for the passage of the second spinal nerve; this is situated immediately below the one on the upper border for the vertebral artery and sub-occipital nerve. These grooves make this the weakest part of the ring of the atlas, but strength is not here required, as no weight has to be transmitted, and no muscles and no ligaments of importance are attached. The posterior tubercle, from which muscles do arise, is thick and tuberculated. The space between the anterior borders of the facets for the axis is from one-eighth to two-eighths of an inch less than that between the sockets for the condyles, and the lower edge of the ring running upwards from them gradually rises in a curved manner to the anterior tubercle. On the posterior aspect of this tubercle is a circular and concave facet, for the odontoid process of the axis, which usually extends the whole depth of the bone, and is about three-eighths of an inch in diameter.

THE AXIS has a body and four articular processes like the rest of the vertebræ*;* what distinguishes it from all the others is the odontoid process, round which the atlas with the head rotates; the breadth and strength of its spinous process, which gives attachment to muscles which move the skull and atlas upon it; the shortness of its transverse processes, which are merely rudimentary and are interposed between the superior articular processes above and in front, and the inferior which are behind and below it; and the prolongation downwards of the forepart of the body, together with the deep depression on either side of the middle line in front, for the attachment of muscles.

The odontoid process, which is about three-quarters of an inch in height, projects upwards from the body of the axis so as to occupy the anterior and smaller portion of the ring of the atlas.

It is rather in front of the line through the centre of the condyles of the occiput, and would bisect, if extended upwards, a line drawn between the anterior border of the jugular processes of the occiput. It tapers somewhat towards the summit where the check and central occipito-odontoid ligaments are attached. Its base is strengthened by a strong vertical ridge which extends downwards upon the front of the body, and by two lateral ridges which curve outwards on each side to the superior articular facets. In front and behind, the process is marked by two convex articular surfaces; that in front, being for the facet on the back of the anterior tubercle of the atlas; and that behind, which is somewhat lower down than the anterior, for the transverse ligament of the atlas. Below these articular facets the odontoid is constricted slightly into what is called the neck.

The superior articular facets are situated partly upon the body and partly upon the arch of the axis, and from their under aspect strong buttresses slope downwards and inwards towards the lower part of the body. The facets are somewhat oblique, being inclined a little outwards and upwards, so that the weight which they sustain is conveyed chiefly downwards and inwards along the buttresses to the lower surface of the body, and is thence transmitted to the body of the third vertebra; but it is partly conveyed downwards and backwards through the strong short pedicles to the inferior articular processes, and through them to the articular processes of the vertebræ below. Like the inferior articular facets of the atlas they are rounded in outline, but their long axis is directed obliquely forwards and inwards, and measures about three-quarters of an inch, while the transverse diameter is not more than half an inch. They are considerably undermined beneath their external borders by the canal for the vertebral artery, which forms a sort of archway between the buttress projecting downwards in front, and the pedicle which curves downwards behind. Behind the lateral articular facets the pedicles are grooved for the second spinal nerve, which like the sub-occipital passes out of the canal behind the articular processes, instead of in front of them, as is the case with all the succeeding.

The inferior articular processes descend from the junction of the pedicle and lamina, and have in front of them a groove which, with the groove in the pedicle of the third vertebra, forms the intervertebral foramen for the passage of the third spinal nerve.

The transverse process springs by two roots, one continuous with the anterior border of the superior articular facet, and the other springing from the pedicle midway between the upper and the lower articular facets. It is stunted and slender, and the foramen which pierces it obliquely is bounded partly by the edge of the superior articular facet. The ring formed by the axis is about one inch in antero-posterior, and half an inch in transverse diameter. The whole bone is very strong, but the most striking feature about it is the advantageous way in which the superior lateral articular facets are inclined so as to receive the weight of the skull from above, and distribute it, in part, to the articular processes, but chiefly, to the bodies of the vertebræ below.

THE LIGAMENTS.—There are four distinct articulations between the atlas and axis—viz., the two central and the two lateral atlanto-axoidean. The ligaments which hold the bones in close contact—*i.e.*, at these articulations—are the *transverse*, which retains the odontoid process against the front of the atlas; and the *capsular ligaments*, which surround the lateral joints. The ligaments which connect the atlas and axis where they are not in contact are the anterior and posterior atlanto-axoidean.

These ligaments, except the transverse, can be dissected and examined to a great extent without opening the spinal canal.

The Anterior Atlanto-axoidean Ligament is a narrow but strong membrane extending from the lower border and front surface of the atlas, where it is blended with the periosteum, to the front of the axis, and fills up the narrow interval between the lateral atlanto-axoidean joints. The fibres of which it is composed are vertical, and those in the median line are more numerous than those at either side, so as to form a dense central band, which is continued into the occipito-atlantal ligament above, and continues upwards the anterior common vertebral ligament from below. This central portion of the ligament is tense in all positions of the joints, while the lateral portions assist in limiting the rotation of the atlas upon the axis.

The Posterior Atlanto-axoidean Ligament is a deeper but thinner and looser membrane than the anterior. It extends from the posterior root of the transverse process of one side to that of the other, and therefore projects outwards beyond the posterior part of the capsules which are connected with it. It is perforated on each side by the second spinal nerve. It is attached above to the posterior surface and lower edge of the ring of the atlas, and below to the superior edge of the arch of the axis at its dorsal aspect. Between the posterior tubercle of the atlas and the spinous process of the axis the ligament is denser and much stronger than on either side.

This ligament has upon its deep or anterior surface a layer of dense yellow fibres, resembling those composing the ligamenta subflava.

The Lateral Atlanto-axoidean Joints.

The Capsular Ligaments are very loose sacs completely surrounding the lateral articular facets. Outside the canal the fibres are attached to the bones at some distance from the edges of the articular surfaces. They extend along the anterior and posterior roots of the transverse process nearly to the tip, but between the roots are inserted into the edge of bone above the foramen for the vertebral artery. Behind, each capsule is thickened by the posterior, and in front by the anterior atlanto-axoidean ligaments. On the inner side the capsule is thinner; the fibres are attached nearer to the edges of the articular surfaces, and are blended at their attachments with some of the other intra-spinal ligaments, and especially with the edge of the occipito-cervical, and the transverse, and lower half of the vertical portions of the crucial ligaments. There is a strong band of slightly oblique fibres thickening the capsule behind, and passing upwards and outwards, along the border of the occipito-cervical ligament, from the lower part of the body of the axis to the atlas just posterior to the attachment of the transverse ligament; some of these fibres pass further upwards, thicken and blend with the capsule of the occipito-atlantal joint, and get insertion at the margin of the foramen magnum. These oblique fibres help to check rotation of the head, and like the anterior atlanto-axoidean ligament, by being attached to the atlas itself, they serve to prevent the atlas from rotating further, after the skull has been stopped by the pull of the check ligaments on the occiput.

SYNOVIAL MEMBRANE.—A synovial membrane lines the fibrous capsule of each of these joints.

The Central Atlanto-axoidean Joints.

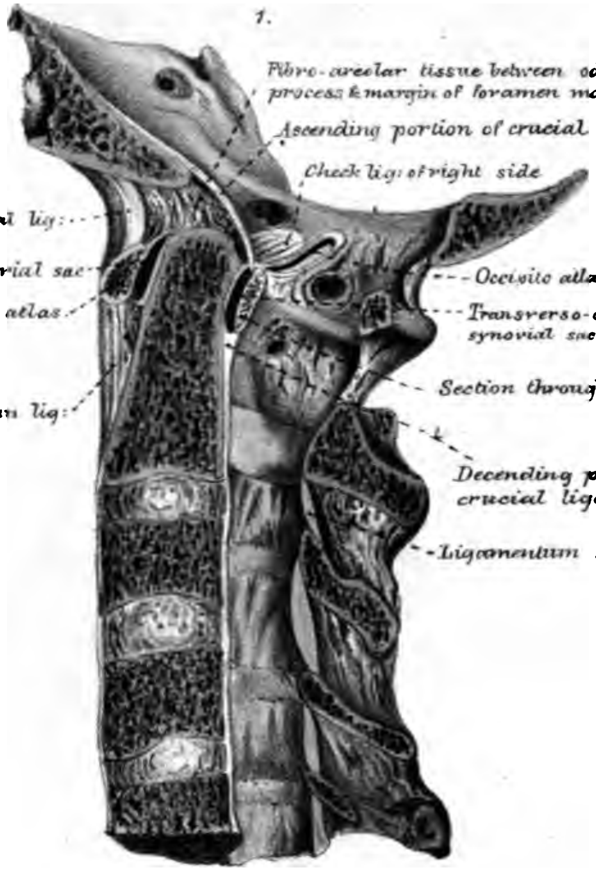
The articulations between the odontoid process, atlas, and transverse ligament are generally described as one joint of the lateral hinge kind. In reality there are two joints quite separate from one another, though the synovial sac of the posterior is not quite distinct, as it communicates with the joints between the occiput and atlas. The movements which occur are like those between the head of the radius and the ulna; but instead of the pivot quite filling the ring and rotating in contact with it all around, it is in apposition only at two spots, and elsewhere ligamentous fibres pass between the pivot and the ring. The movements rather than the anatomy of the joint require it to be classed as *Trochoides.*

The Transverse Ligament is one of the most important structures in the body, for upon its integrity the life of each one of us depends. When it becomes destroyed by disease or broken by accident the odontoid process, no longer held forwards against the front part of the ring of the atlas, is free on the slightest movement to tilt backwards and press upon the medulla oblongata. It is a thick and very strong band, which crosses the ring of the atlas in a curved way so as to have its concavity forwards. At its ends it is attached to the tubercle on the inner surface of each lateral mass, so that, with the front arch and the anterior half of each lateral mass of the atlas, it forms a ring which encloses the odontoid process. Its structure is as dense and closely woven as fibro-cartilage; it is about a quarter of an inch in depth at each side, and somewhat more in the middle line, and its anterior surface is smooth and covered with a synovial lining to allow it to glide smoothly upon the posterior facet of the odontoid. The synovial cavity communicates with the anterior portion of the occipito-atlantal joints, and is closed in above and below by some loose fibro-cellular tissue between the upper and lower border of the transverse ligament, and the margins of the articular facet upon the posterior aspect of the neck of the odontoid. It is separated from the synovial cavity of the atlanto-odontoid joint by some very strong, short

PLATE

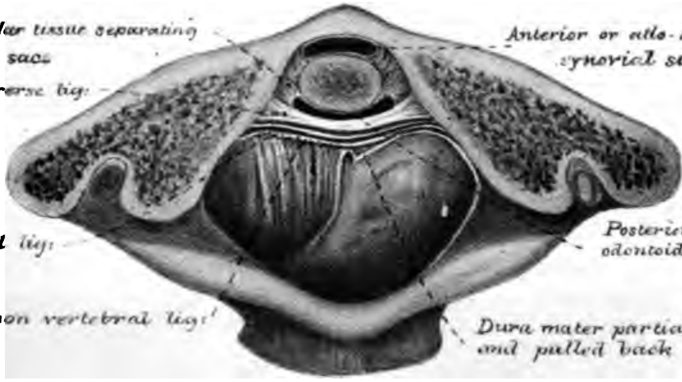
VERTICAL SECTION THROUGH ATLO-ODONTOID OR CENTRAL ATLANTO-AXOIDEAN JOINTS.

1.


Fibro-areolar tissue between odontoid process & margin of foramen magnum
Ascending portion of crucial ligament
Check lig: of right side
occipito-atloidal lig:
dontoid synovial sac
Section of atlas
- - - Occipito atlantal joint
- - - Transverso-odontoid synovial sac
tlanto-axoidean lig:
Section through transvers
Decending portion of crucial ligament
Ligamentum subflavum

HORIZONTAL SECTION THROUGH CENTRAL ALTO-AXOIDEAN JOINTS

2.


- areolar tissue separating
noval sacs
Transverse lig:
Anterior or atlo-odontoid synovial sac
ervical lig:
Posterior or transve odontoid synovial
common vertebral lig:
Dura mater partially detac and pulled back

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ligamentous fibres, which pass from the margins of the articular facet on the front of the odontoid, to the grooves in front of the tubercles for the transverse ligament. These fibres help to form a complete capsule for the joint between the atlas and odontoid process. The transverse ligament where attached to the atlas is well rounded off and very smooth, so as to provide a gradual and easy floor of communication between the *transverso-odontoid synovial sac* and those of the occipito-atlantal joints.

Passing upwards and downwards from the transverse ligament in the middle line is a strong band of vertical fibres, which, together with the transverse, forms what is called the crucial ligament—the third in order of depth of the ligaments connecting the occiput and axis.

The Atlo-odontoid Capsular Ligament.—The apposed articular surfaces of the atlas and axis are completely surrounded by a tough, loose membrane of strong fibres which forms a perfectly separate synovial cavity for this joint. These fibres at the odontoid process are united above with the front of the check and the central occipito-odontoid ligaments, and arise all along the sides of the articular facet as far as the neck of the process, where they are very thick and blend with the capsule of the lateral atlo-axoidean joint. At the atlas the fibres are attached from upper to lower border to the wide groove in front of the tubercles for the transverse ligament, while above and below the borders of the bone they blend with the back of the anterior occipito-atlantal and atlo-axoidean ligaments, and with the inner part of the capsular ligaments between the occiput and atlas, and atlas and axis.

This ligament holds the axis to the front part of the ring of the atlas after the crucial, check, and capsular ligaments of the lateral joints have all been divided.

SYNOVIAL MEMBRANE.—There are two synovial sacs in connexion with the central atlo-axoidean or atlo-odontoid articulations—viz., one for the joint between the transverse ligament and the back of the odontoid which communicates with the occipito-atlantal synovial sacs; and one for the joint between the central facet of the atlas and the facet on the front surface of the odontoid.

ARTERIES.—Blood is supplied to the atlanto-axoidean joints from branches of the vertebral artery.

NERVES.—Twigs are derived from the second cervical or the loop between it and the sub-occipital.

MUSCLES.—The description of the muscles will follow that of the ligaments between the occiput and axis.

THE MOVEMENTS BETWEEN THE ATLAS AND AXIS.—The chief as well as the characteristic movements between these bones is rotation, in a nearly horizontal plane, of the collar formed by the anterior part of the atlas and the transverse ligament, round the pivot formed by the odontoid process. In this movement the head is carried with the atlas, partly on account of the ligaments uniting the atlas with the occiput, and partly on account of the shape of the articular surfaces of these bones, which renders it impossible for the atlas to rotate by itself between the head above and the axis below. Moreover, some of the muscles which assist in producing the rotatory movements are inserted into the occiput, and so make traction upon the head, at the same time that the inferior oblique muscle pulls upon the atlas. The degree of this rotation may be estimated by remembering that man can take a complete survey around him by simply moving the head from side to side without twisting or turning the trunk. This rotation is checked partly by ligaments passing from axis to occiput, and partly by the atlanto-axoidean ligaments; it is clear that just as the ligaments uniting atlas to occiput will tend to drag occiput with atlas round the axis, so those uniting atlas and axis will tend to check rotation of atlas beyond a certain point.

The shape of the articular surfaces upon which this rotation occurs, is such, that the movement is not in an accurately horizontal plane, but in a slightly curvilinear direction. In the dry bones, and still more in the recent state when coated with articular cartilage, the facets of the atlas, though of nearly the same size and outline, are so ill adapted to those of the axis upon which they move, that their surfaces are never in complete contact. This is owing to the fact that both sets of facets are convex from before backwards, and have thicker articular cartilage in their centres than at their edges. Consequently when the head is erect the most convex portions are in contact, and there is a considerable gap between their circumferential surfaces; but during rotation these lateral facets of the atlas glide obliquely upon those of the axis, so as to project beyond them—in front on one side and behind on the other—and in doing so the convex central part of the facets of the atlas leave the convex central part of those of the axis, and descend, the one forwards and the other backwards. In this way the space between the bones is diminished to an extent corresponding to the degree of rotation, so that the ligaments are slackened, as it were, in their vertical direction to provide for their lengthening in an obliquely transverse one. Were this not the case rotation would be very limited or impossible; or would be possible only at the expense of the security of union of the head with the spine, for the length of ligament which would be requisite for the rotation of accurately apposed surfaces upon one another in a truly horizontal plane, would necessitate their being slack when the erect and non-rotated position was assumed.

It must not be supposed, however, as seems sometimes to be done, that the ligaments which pass over the odontoid process to the occiput are always quite tight when the head is straight. Were this the case no forward flexion would be possible; but this movement is we know permitted to a great extent at the occipito-atlantal, and to a less extent at the lateral atlanto-axoidean joints. The fact is that muscular action, not ligamentous tension, is employed for steadying the head in the erect position, and that the vertical intra-spinal ligaments between the skull and column are not rendered quite tight until the head droops forward, nor the check and other oblique ligaments until rotation is completed.

Besides rotation, forward and backward movements and some lateral flexion, are permitted between the altas and axis as well as between the other vertebræ. Indeed, even to a greater extent than in most of the other vertebral joints. The pivot of the axis is not so tightly embraced by its collar as to limit these movements to the same degree that the intervertebral substances do the movements of the other vertebræ; while the want of coaptation of the lateral articular facets, together with their forward position on the bones, their obliquely horizontal direction, and loose capsular ligaments, favour motion round an antero-posterior as well as a transverse axis.

The Ligaments uniting the Occiput and Axis.

These connect bones not in contact. They are all to be seen from within the spinal canal after removing the posterior arch of the axis, and the back part of the rings of the atlas and of the foramen magnum. They are arranged in four strata beneath the dura mater and the continuation upwards to the occiput of the posterior common vertebral ligament; (1) the occipito-cervical ligament; (2) the ascending part of the crucial ligament—the occipito-axoidean; (3) the central occipito-odontoid ligament. The fibres of all these take a vertical or nearly vertical course, but there are in addition to them (4) two ligaments—viz., the check ligaments, which are almost transverse in direction, one on each side, and which are in a position between the second and third strata.

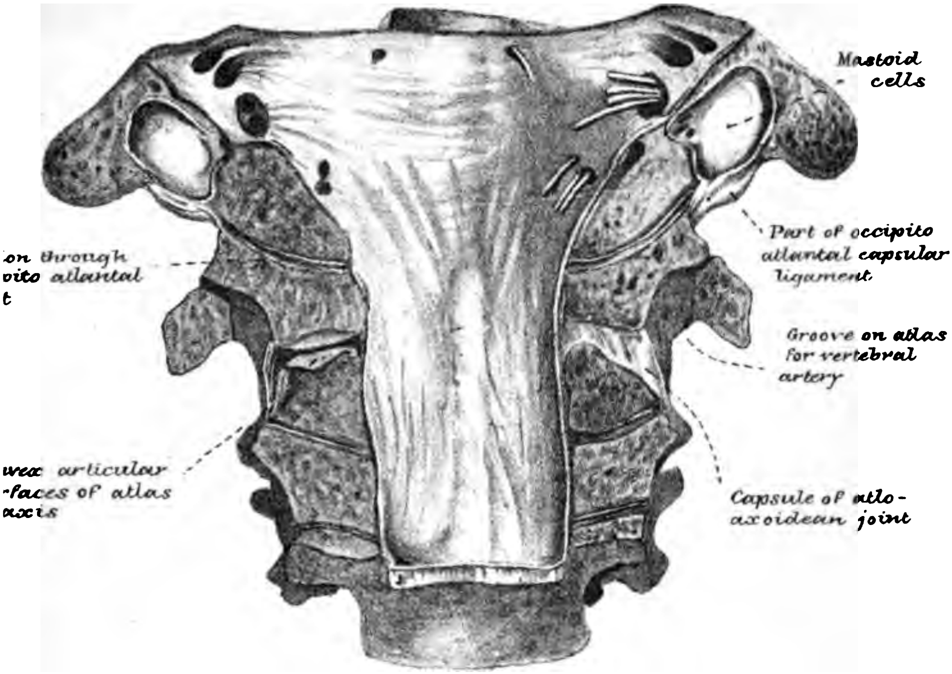
The posterior common vertebral ligament passes over the odontoid and reaches as far upwards and forwards as the posterior clinoid processes and the petrous portion of the temporal bone. Between the body of the third cervical vertebra, to which it is attached, and the points of the skull just named, it lies upon the following strata of ligaments—viz.:

The Occipito-cervical, or Cervico-basilar Ligament. This is a very strong band of fibres connected below to the upper part of the body of the third vertebra, and the lower part of the body of the axis, on their posterior aspect, and above to the basilar groove of the occiput. It is narrow below, but widens out as it passes upwards, and along its lateral borders it is connected with some strong scattered fibres which are auxiliary to the capsules of the atlanto-axoidean joints.

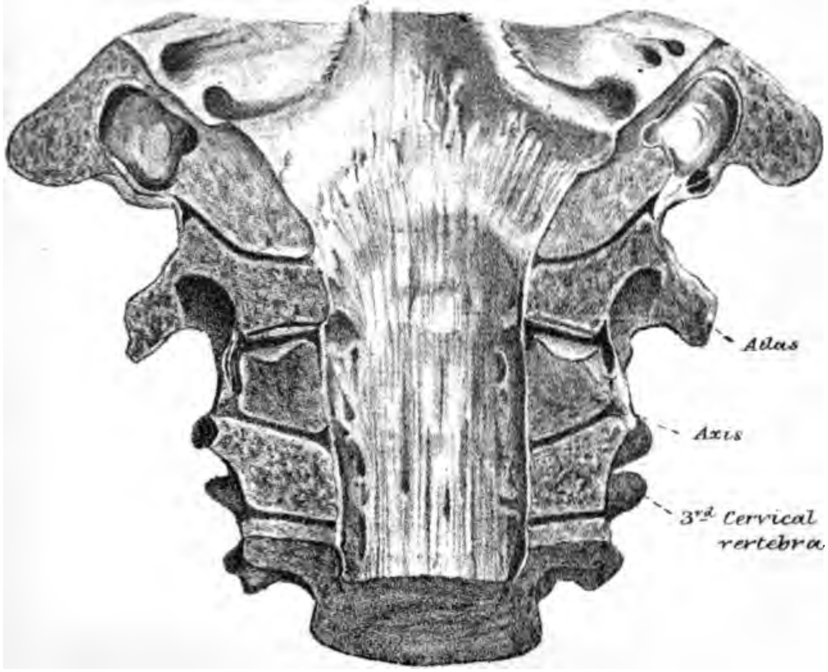
The *Crucial Ligament* is exposed after reflecting the foregoing. Its stronger portion is the *transverse ligament,* which extends from side to side of the atlas and forms the back part of the encircling collar which plays round the odontoid pivot: it has been described with the ligaments of the atlo-axoidean articulation. The *vertical part* or *occipito-axoidean ligament* consists of parallel bundles of strong fibres posterior to, but closely connected with, the transverse ligament, from which indeed some of its fibres are derived; it extends from the upper half of the body of the axis to the basilar border of the foramen magnum on the cranial surface. It thus assists the two previous strata of ligaments in holding the odontoid process in its place with respect to the skull; while its transverse part holds the same process in its place with reference to the atlas. These three ligaments check the flexion or nodding movements of the head upon the spine.

TRANSVERSE SECTION THROUGH OCCIPUT & UPPER FOUR CERVICAL VERTEBRÆ

1 . Showing dura mater in situ


Mastoid cells
on through
pito atlantal
t
Part of occipito atlantal capsular ligament
Groove on atlas for vertebral artery
vex articular
-faces of atlas
axis
Capsule of atlo-axoidean joint

2 Posterior common vertebral ligament seen after removing the dura mater



The convex surfaces of both bones at atlo-axoidean joint are well seen

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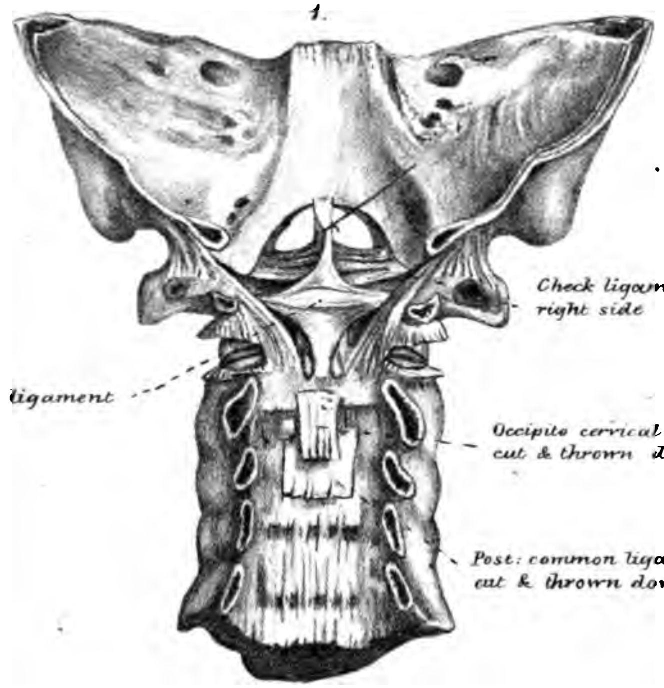
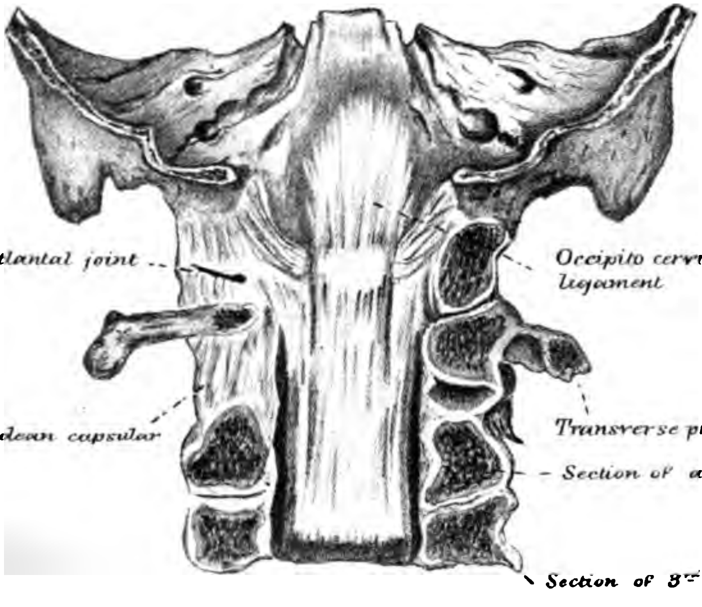
LIGAMENTS CONNECTING THE HEAD WITH THE SPINAL COLUMN

1.


Check ligament of right side
Crucial ligament
Occipito cervical ligament cut & thrown down
Post: common ligament cut & thrown down

A.Hensman del. ad. nat.

2.


Occipito atlantal joint cut into
Occipito cervical ligament
Atlo-axoidean capsular ligament
Transverse process of atl
Section of axis
Section of 3rd vertebra

at

West Newman & Co lith

The *Occipito-odontoid Ligaments*, on a deeper or more anterior stratum than the crucial ligament, are the two check ligaments and the central odontoid. The *central occipito-odontoid ligament*, sometimes called the suspensory ligament, consists of a slender band of fibres which passes from the summit of the odontoid process to the under surface of the basilar bone close to the foramen magnum. It is best seen from in front after removing the anterior occipito-atlantal ligament, but can be seen from within by drawing aside the upper part of the crucial ligament. It is relaxed not tightened by flexion or nodding, and serves to check the extension of the skull on the spine.

The *Check Ligaments* extend from the sides of the truncated summit of the odontoid transversely outwards to the inner edge of the anterior portion of the occipital condyles. They are to be seen immediately above the upper border of the transverse ligament, which they cross obliquely, owing to the forward curve of the transverse ligament as it approaches the tubercles of the lateral masses of the atlas. At the odontoid process they are connected with the tough loose fibres which connect that process with the anterior arch of the atlas and enclose the synovial cavity of the central atlanto-axoidean joint, and at the condyles they strengthen the inner part of the occipito-atlantal capsules.

They limit the rotatory movements of the head and atlas upon the axis, and what is more, by binding the occiput to the pivot round which the rotation occurs, they steady the head, and prevent its undue lateral inclination upon the spine.

By experiments it has been proved that the head, when placed so that the orbits look a little upwards, balances upon the occipital condyles in a transverse line drawn a little in front of their middle. To obtain this balance the amount of elevation varies slightly in different cases, but the balance is always to be obtained in the human body, to which it is peculiar. This balancing of the head is sufficient for maintaining the erect posture without undue strain upon muscles; or the development of any such powerful structure as the ligamentum nuchæ, and the prominence of the dorsal spinous process, such as is seen in the lower animals. But when the head is so placed that the orbits are directed forwards, or a little downwards, the balance being disturbed, the head would fall forwards were it not for the muscles of the back of the neck. Hence when the muscles cease to act from any cause, such as sleep, injury, or disease, the head droops, the chin falls, and pain is experienced from the tension made upon the ligaments which check the nodding or anterior flexion movements.

It is, however, perfectly familiar to every one that the head will sometimes drop backwards on the cessation of muscular action, as during sleep when the face is turned considerably upwards. This shows that the line of gravity of the head can be thrown backwards beyond the balance plane through the condyles. From the condyles the weight is transmitted through the lateral masses of the atlas, the lower facets of which look downwards and inwards; and thence to the superior articular facets of the axis which look upwards and outwards. These last are placed partly over the body of the axis and partly over the pedicles, so as to form a kind of bridge above the intervertebral foramen for the third cervical nerve. From these facets the weight is directed chiefly downwards and inwards to the lower part of the body of the axis, but also to a less extent downwards, outwards, and backwards to the inferior articular facets of the axis, and thence onwards through the bodies and articular processes of the rest of the vertebræ.

Although, as has been said, the head would but for muscular action fall forwards, until checked by the ligaments which ascend to the occiput, when the line of gravity is in front of the condyles; it must be admitted that, *in spite of muscular action*, the atlas would have a tendency to fall away from the odontoid process were it not for the transverse portion of the crucial ligament, and the atlo-odontoid capsular ligament. Still, even when these are divided, there yet remain the ligaments ascending over the odontoid to the occiput to resist the backward displacement of the odontoid process, while the action of the inferior oblique muscles, when acting together, is to hold back the atlas against the odontoid. In order therefore that the odontoid process should fall back and impale, as it were, the medulla oblongata (as has not unfrequently happened in cases of sudden death from disease of the upper end of the spine), it is necessary that all the four strata of ligaments which connect the skull to the axis should be destroyed, as well as the atlanto-odontoid capsule and the transverse portion of the crucial ligament.

Regarding all these several joints and ligaments as entering into the union of the head with the column—as indeed they truly do—it may be stated that the skull is connected with the spine by two pairs of joints, placed one above the other, and arranged symmetrically on each side of the median line, and that through the median line there passes a pivot, which is also provided with a pair of joints, but placed one in front of the other. At these joints the movements are so various and so rapidly executed, that they would not have been possible at any single joint, excepting of the universal or ball and socket kind. Now, although a ball and socket joint can be made compatible with great strength, as we see in the hip-joints, yet such joints are very prone to dislocations from even moderate twisting forces, and therefore their security is not sufficient for parts such as those under consideration, where the life of the individual depends upon the perfection of the articulations. As it is, through the combination of six several joints the head enjoys freedom of movement, remarkable strength, almost absolute security from violence, and a fairly broad basis of support. This basis consists of articular masses which are placed symmetrically on each side of the line of gravity, and converge as they descend to the body of the axis.

It will be well again to observe that such are the connexions between the occiput, atlas, and axis, that anything which tends to check rotation through its attachment to the occiput will also act *indirectly* upon the atlas; while at the same time parts of the atlanto-axoidean ligaments tend *directly* to check the rotation of the atlas. Conversely, whatever acts upon the atlas to produce rotation, indirectly acts upon the head with the same result; while at the same time there are muscles attached to the head which produce rotation by their *indirect* action, through the occipito-atlantal ligaments, upon the atlas.

Muscles connecting the Head with the Spine, or moving the Head upon the Spine.

These may be conveniently and simply classed into two sets—those in front of, and those behind, the column: while each of these may be subdivided into the short cranio-vertebral and long muscles.

1. The muscles in front of the column consist of the prævertebral muscles strictly so called—viz., the anterior recti and

a thin aponeurosis to the protuberance, and the inner third of the superior curved line, of the occipital bone, acts on the head when the upper extremity is in a fixed condition. If the upper parts of both trapezii act together they extend the head by pulling it backwards on the atlas. They thus assist the sterno-mastoid in depressing the occiput, and throwing forwards and upward the chin. When one trapezius acts alone it assists the sterno-mastoid of its own side to draw the head downwards and forwards in such a manner that while the occipital protuberance approaches the shoulder of its own side the chin is raised and turned towards the shoulder of the opposite. This movement involves both sets of joints; rotation occurs at the atlanto-axial, and flexion at the occipito-atlantal as well as at the atlanto-axial. It will be remembered that these muscles are brought into very intimate association by their nerve supply, the spinal accessory being distributed between them.

The splenius capitis and the trachelo-mastoid, which pass upwards and outwards to the mastoid process of the temporal bone and the outer part of the superior curved line of the occipital, rotate the head and atlas on the axis, so as to turn the face towards their own side; they also incline the head backwards and to their own side. Their pull being exerted on the head, they act indirectly upon the atlanto-axial, directly on the occipito-atlantal joints. When the muscles of both sides act together they extend the head—*i.e.*, draw it backwards. They are assisted in this action by the splenius colli, which acts upon the upper cervical vertebra. The splenii and trachelo-mastoid are the antagonists of the sterno-mastoid; when they act with the sterno-mastoid they draw the ear to the shoulder. The complexus, which extends from the transverse and articular processes, as well as from the capsular ligaments of the vertebræ to the large impression between the two curved lines of the occiput near the occipital crest, is also an extensor of the head, and acts as such in conjunction with the muscle of the opposite side, and the rest of the muscles of the back which extend to the head. When the complexus of one side only acts it serves to draw the head backwards obliquely to its own side, instead of directly backwards as when both muscles act together.

PART II.

CHAPTER V.

THE TRUNK.

The Ligaments and Joints of the Spinal Column, or the connexion of the Vertebræ with one another.

TWENTY-FOUR vertebræ, articulated together, assist in forming the spinal column; seven are in the neck, twelve have ribs connected with them and contribute to form the thorax, and five are in the loins. Each vertebra articulates with those adjacent to it by means of its body and articular processes; in the case of the first vertebra, the body of which is represented by the odontoid process of the axis, a special articulation is provided between the ring of the atlas and the odontoid, as has been described under "The Ligaments and Joints connecting the Head with the Spinal Column." Between the bodies of all the other vertebræ, as well as between the last lumbar and the base of the sacrum, a tough and elastic substance consisting of fibrous tissue and fibro-cartilage, and called an *intervertebral substance,* is interposed. Thus, in addition to the twenty-four vertebræ, there are twenty-three intervertebral substances in the spinal column.

The column may conveniently be divided into two parts—an *anterior,* consisting of the bodies of the vertebræ and the intervertebral substances; and a *posterior,* consisting of the arches of the vertebræ with their outstanding processes. These two parts which together complete the canal for the protection of the spinal cord, may be separated from one another so as to leave the ligaments and intervertebral substances intact, by dividing the pedicles of the vertebræ, which are devoid of all ligamentous attachments.

The bodies of the vertebræ support and transmit the weight of the head and trunk, while each is capable through the agency of the intervertebral substances of some slight movements upon the others.

The Articular Processes have for their chief purpose to preserve the proper relation of the arches of the vertebræ to one another during the movements of the bodies; while at the same time they provide smooth, gliding surfaces whereby each arch may yield with the bending or tilting of the corresponding body upon the intervertebral substance.

The Laminæ, by closing the spinal canal upon its more superficial and exposed aspect, afford protection to the spinal cord, and are in their turn protected by the spinous processes which stand backwards from them, as well as by the mass of spinal muscles resting upon them. To these laminæ are attached a series of short elastic springs, whereby the column is restored to its natural form after any movement of the vertebræ upon one another.

The Spinous and Transverse Processes serve for the origin and insertion of the muscles of the back and some of those of the trunk; their connexion with ligaments is insignificant and altogether secondary. In addition to affording attachment and leverage for muscles, the transverse processes in the dorsal region give support to the necks and tubercles of the ribs.

The Pedicles serve to carry the processes and laminæ away from the bodies, and to form the buttresses of the arches which cover in the spinal canal.

The ligaments of the spine are connected with all the several parts of the vertebræ except the pedicles; but those passing between the transverse and spinous processes, excepting perhaps the supra-spinous ligament, are of but little consequence and use—if indeed they have any such as belongs to ligaments proper.

The ligaments which bind together (1) the bodies and intervertebral substances and (2) the articular processes, are the *immediate* ligaments of the spine, because they connect parts which are in contact; those, on the other hand, which pass between (1) the laminæ and (2) the non-articular processes, are the *mediate* ligaments of the spine, because they connect parts which are not in contact.

It must be remarked, however, that the ligamenta subflava are both mediate and immediate ligaments; mediate in so far as they pass from one lamina to the next, but *immediate* in so far as they form parts of the capsules of the articulating processes.

Between the pedicles of one vertebra and those of the next no ligament extends, so that spaces are left between them, called the intervertebral foramina, through which the spinal nerves emerge from the canal.

Having made these general remarks upon the several parts of which the spine consists, and of the connexion of these parts with one another, we now proceed to the detailed consideration of the two portions of the vertebral column as above defined—viz., the anterior and posterior.

Articulations of Bodies of Vertebræ.

Class, Amphiarthrosis.

The Anterior Portion of the Column consists of the (1) bodies of the vertebræ, (2) the intervertebral substances, and (3) the ligaments which bind them together.

THE BODIES OF THE VERTEBRÆ are more or less rounded flattened discs, the width of which is nearly twice that of their depth. They are composed of porous, spongy bone, surrounded by a thin layer of compact tissue which becomes thicker towards the upper and lower surfaces of the vertebræ, and is there seen, on the dry bones, to form a narrow white border which is most strongly marked towards the front, more especially in the dorsal region.

To this white border or circumference of the upper and lower surfaces of the body, some of the lamellæ of which the intervertebral substances are partly formed are immediately attached. Within this border, the spongy, porous character of the bone extends to the surface of the bodies, but this is covered in the recent state by a thin plate of articular cartilage which separates the less perfect lamellæ and the central pulpy portions of the intervertebral substances from immediate contact with the bone. While they are convex from side to side, and concave from above downwards *in front* of the arches, they are concave from side to side, and flat from above downwards *behind* (*i.e.*, between the pedicles) in the dorsal and lumbar regions, and flat from side to side as well as from above downwards in the cervical region. On the upper and lower surfaces the border of compact bone rises somewhat above the rest of the surface, which is thus made slightly concave. In the cervical region the border of the upper surface projects upwards at the back, and still more so at the sides, but is bevelled off in front; on the under surface the border is bevelled off on the sides, but projects downwards both in front and behind. It is thus impossible to place the bodies of two cervical vertebræ in apposition with one another, as may be done with the dorsal and lumbar vertebræ, an interval of considerable size filled up of course in the recent state by intervertebral substance always existing between them in the dry state.

The bodies of the vertebræ increase in size and weight from above downwards, although those of some of the lower cervical and the three upper dorsal appear larger when looked at from in front than do the bodies of some of the vertebræ immediately below them. This is partly owing to the difference of shape in the bodies themselves, and partly to the forward position of the transverse processes in the cervical region.

In the cervical and lumbar regions the transverse is greater than the antero-posterior measurement of the bodies; in the dorsal vertebræ these two measurements are equal, or nearly so. As seen from the upper and lower surfaces of the bodies of the dorsal vertebræ, the cortical layer of compact bone is much thicker at the forepart than at the sides; this is on account of the concavity forwards of the dorsal curve of the column and the consequent strain along the front of the bodies made by the superincumbent weight of the head and trunk. It is usually stated that the cervical and lumbar vertebræ are deeper in front than behind, but this is hardly correct. There is no uniformity whatever in the relative depths of the anterior and posterior surfaces of the cervical vertebræ; some are equal in front and behind, others a little deeper behind than in front; but when all the cervical vertebræ are placed firmly together without their intervertebral substances there is a very slight concavity in front. In a good representative set of vertebræ taken without selection, the measurement along the posterior surface of the bodies of the lower five cervical vertebræ when closely applied to each other was $2\frac{7}{8}$ inches, while along the front it was 2½ inches; and when all the cervical vertebræ were placed firmly together, the measurement along the back of the bodies was 4½ inches, and along the front 4¼ inches.

In the lumbar region when the dry bones are examined alone—*i.e.*, without intervertebral substance—there is usually though not invariably a slight convexity in front owing to the projection forwards of the third and fourth bones. From the upper edge of the eleventh dorsal to the lower edge of the fourth lumbar vertebra, there is a gradual sloping forwards from above; the fifth recedes slightly. The five lumbar vertebræ when closely applied to one another, measured 5¼ inches along the front, and 5⅛ inches along the back of their bodies. This one-eighth excess in front was exactly equivalent to the greater anterior depth of the fifth vertebra. The third bone was nearly uniform throughout, but while the first and second were somewhat deeper behind (in this, resembling the dorsal vertebræ) than in front, the difference was counterbalanced by the fourth, which was deeper in front than behind.

The bodies of the dorsal vertebræ are deeper behind than in front, some of them showing more difference in this respect than others. Along the back of the twelve dorsal vertebræ closely applied together the measurement was 11 inches, while along the front it was 9¾ inches.

THE INTERVERTEBRAL SUBSTANCES are tough but elastic and compressible discs of composite structure, which serve as the chief bond of union between the vertebræ. They are twenty-three in number, and are interposed between the bodies of all the vertebræ from the axis downwards. Similar substances occur likewise between the segments of the sacrum, and of the coccyx, but they undergo ossification at their surfaces and often throughout their extent. Between the sacrum and coccyx there is a very perfect little disc of the same general characters and structure as those between the vertebræ. The description of the sacrum and coccyx, however, is not included in the description of the spinal column, but falls more naturally under the section " Pelvis."

The intervertebral substances differ from every other structure in the body; though not truly ligamentous nor truly cartilaginous, they are of an intermediate nature. Each disc is composed of a circumferential laminar and a central soft pulpy portion; the former tightly surrounds and braces in the latter, and forms somewhat more than half the disc. The laminar portion consists of alternate layers of fibrous tissue and fibro-cartilage. The component fibres of these lamellæ are firmly connected with two vertebræ and pass obliquely between their opposing surfaces in such a way that those of one lamella descend from left to right, while those of the next pass from right to left. A few of the superficial lamellæ project slightly beyond the edges of the bodies, and their fibres are connected with the edge of the anterior and lateral surfaces of the vertebræ; some of these lamellæ do not completely surround the rest, but terminate at the intervertebral notches, so that a horizontal section shows the circumferential portion as being thinner at the posterior part than elsewhere.

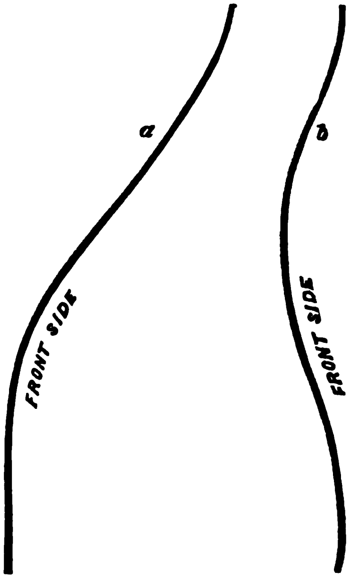
The more central lamellæ are incomplete, and less firm and distinct than the rest; while those nearest the pulp become more fibro-cartilaginous and less fibrous in structure, have cartilage cells and fluid amongst them, and gradually assume more and more the character of the pulpy material.

The pulpy portion is somewhat behind the centre of the disc, and is so soft and elastic that when the confining pressure of the laminar portion is removed, by making either a vertical or a horizontal section, it bulges freely or rises up considerably into a smooth and rounded eminence. It is yellowish in colour, and is composed of loose cartilaginous substance, with a large quantity of fluid and many cartilage cells in the interspaces of its matrix. It is the persistent part of the chorda dorsalis.

It is not in immediate contact with the bodies of the vertebræ, but together with some of the most central and imperfect lamellæ it is separated from the bone by a thin layer of articular cartilage. It forms a ball of tightly compressed and elastic material, which has a constant tendency to spring out from its confinement in the direction of least resistance; hence it constitutes a pivot round which the bodies of the vertebræ in contact with it tilt, or on which they twist or incline in one direction or another.

The intervertebral substances vary in shape with the bodies of the vertebræ which they unite. They have therefore a wider area the lower they are situated in the column. Their thickness is also greatest in the lumbar region. Together they form nearly one-quarter of the whole length of the column, so that in a column of twenty-eight inches the intervertebral substances together measure about seven inches. The total length along their front aspect is greater than that along their posterior surface; and this difference is chiefly due to the cervical and lumbar substances. Thus they are the cause of the convexity forwards in the cervical region, and increase that in the lumbar. It will be seen on referring to figure how great is the difference in the curves of the spine (*b*) in the recent state, and (*a*) in the dry after the intervertebral substances have been removed and the vertebræ are placed in close contact with each other, both with respect to their bodies and articular processes. In the dry state the convexity of the cervical and lumbar regions almost disappears, and the vertebræ present one great curve, the concavity of which looks forwards, and is most marked a little below the middle of the dorsal region. Such is the curve of old age, owing to the shrinking and drying up of the intervertebral substances, which in their perfect state not only straighten out the column, but give to it the forward

DIAGRAM I.
Curves of Spinal Column between Atlas and Fifth Lumbar Vertebra.



Without intervertebral substances.

With intervertebral substances.

projections in the cervical and lumbar regions, and produce those gentle curves in the line of the column which have led to its being called "the line of beauty" in all ages.

The concavity forwards of the dorsal region is almost entirely due to the shape of the bodies of the vertebræ, but is somewhat increased by the intervertebral substances.

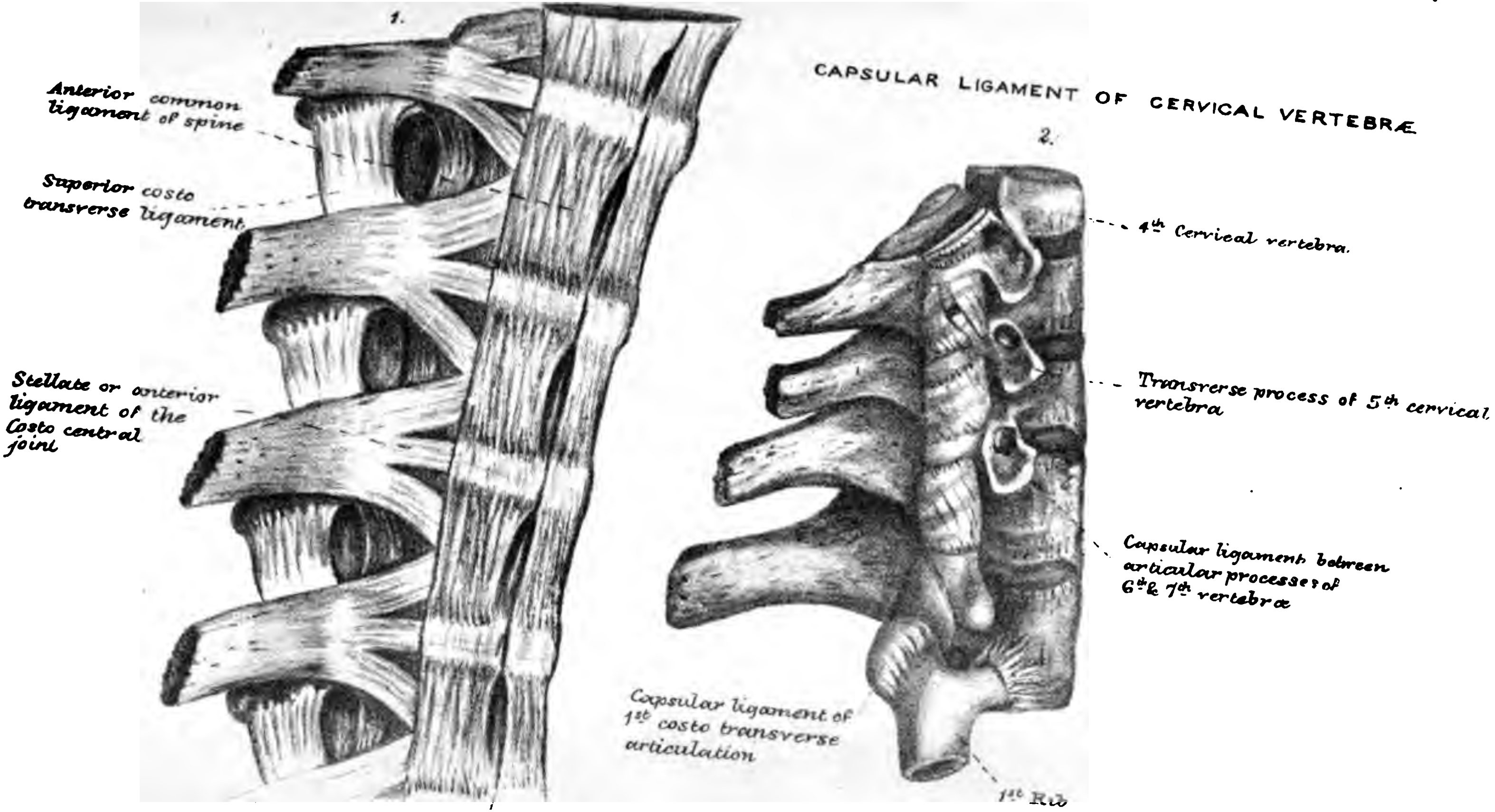
THE LIGAMENTS.—The intervertebral substances are closely bound by the ligaments which pass over them and the bodies of the vertebræ; and in the dorsal region, the inter-articular ligaments of the heads of the ribs are also firmly attached to the intervertebral substances.

By means of the intervertebral substances alone the vertebræ are united together very firmly, in much the same way as the several parts of the pelvis are by their symphysial cartilages; but the column so constructed is too supple and flexible, so that the union of the several segments requires to be further bound together by long, and short immediate ligaments. These ligaments are the anterior and posterior common vertebral, and the short intervertebral ligaments.

Further, the stellate ligaments of the costo-vertebral joints, though not ligaments properly speaking of the spinal column, yet give strength to it by binding two vertebræ and the intervening substance to the same rib or lateral buttress.

The Anterior Common Vertebral Ligament extends, as a very distinct longitudinal band, from the second cervical vertebra to the sacrum. At the middle of the sacrum it becomes gradually lost in the periosteum of that bone, but is again distinguishable as a ligament in front of the sacro-coccygeal articulation.

At its upper extremity it is continuous with the narrow central portion of the anterior atlo-axoidean ligament, which, like it, is firmly connected with the front of the body of the axis. At first narrow and pointed, it gradually widens as it descends, until it measures from one and three-quarters to two inches at the fifth lumbar vertebra. It is thickest in the dorsal region, and thicker in the lumbar than in the cervical region. Its structure is bright pearly white and glistening, with straight and well-defined borders. These borders are particularly well marked in the dorsal region, where, over the bodies of the vertebræ, the finger-nail can be inserted beneath them. The ligament can be detached from end to end as a ribbon-like



CAPSULAR LIGAMENT OF CERVICAL VERTEBRÆ

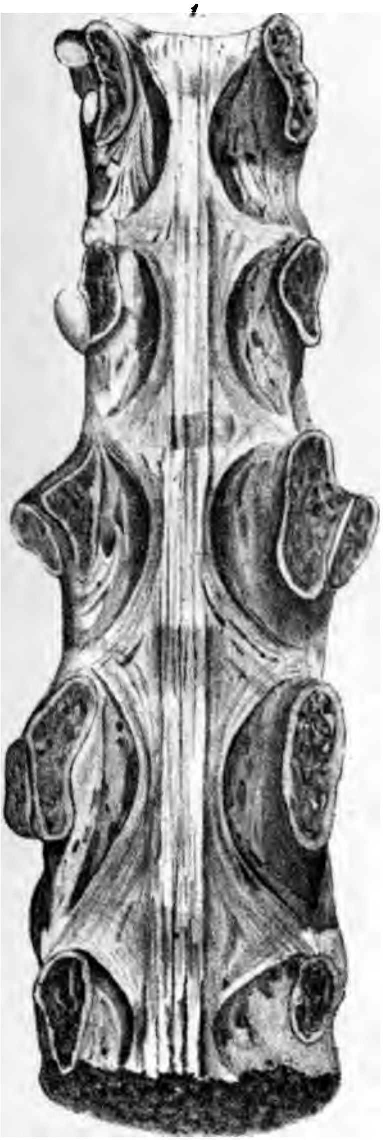
1.
Anterior common ligament of spine
Superior costo transverse ligament
Stellate or anterior ligament of the Costo central joint
2.
4th Cervical vertebra.
Transverse process of 5th cervical vertebra
Capsular ligament between articular processes of 6th & 7th vertebræ
Capsular ligament of 1st costo transverse articulation
1st Rib

POSTERIOR COMMON LIGAMENTS

PLATE VIII.

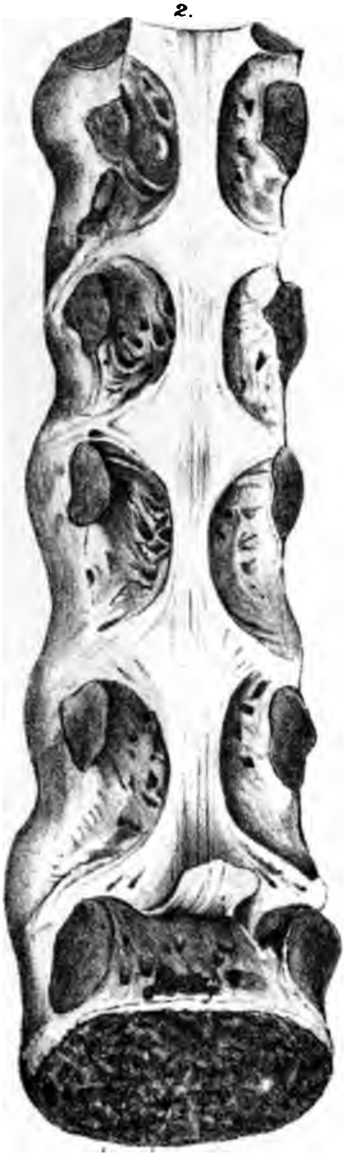
IN THE LOWER HALF OF DORSAL REGION

1.



IN THE LUMBAR REGION.

2.



Lig: turned up showing large foramina for blood vessels in the back of the bone

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band. It is firmly connected with the bodies of the vertebræ. Its superficial fibres extend over several, its deeper over only two or three bones. It is strengthened in the cervical region by the tendinous fibres of the prævertebral muscles, and in the lumbar region by the crura of the diaphragm.

The anterior common ligaments prevent undue backward movement of the vertebræ—*i.e.*, over-extension of the spine.

The Posterior Common Vertebral Ligament extends from the occipital bone to the coccyx. It is wider above than below, and at its commencement has a broad attachment to the cranial surface of the basilar portion of the occipital bone. As it passes over the back of the bodies and intervertebral substances, it varies somewhat in the different regions of the column. Throughout the cervical portion it is of nearly uniform width, although on the level of the intervertebral subtances it retains the same thickness somewhat further outwards on each side than over the bodies of the bones, and it is continuous with the short intervertebral ligaments at the intervertebral foramina.

In the dorsal and lumbar regions it has distinctly dentated borders, being broader over the intervertebral substances and the edges of the bones than over the middle of the bodies of the vertebræ. In the latter situations, where its close attachment to the bone is not requisite for strength, and where numerous bloodvessels pass into and out of the osseous substance, the ligament is a narrow band along the median line. These narrow portions consist of longitudinal fibres, some of which are superficial and pass over several vertebræ, and others are deeper and extend only from one vertebra to the next but one below. The broader portions or expansions of the ligament are formed by oblique fibres, which, springing from the lateral surface of the bodies near the intervertebral foramina, take a curved course downwards and backwards over an intervertebral substance, and reach the narrow portion of the ligament on the centre of the vertebra next below. They again diverge outwards to pass over the next succeeding intervertebral substance, and end on the lateral aspect of the body of the vertebra beyond. The same fibres therefore are in connexion with the bodies of three vertebræ and two intervertebral substances—*i.e.*, two amphiarthrodial joints; they enter into two expansions and decussate in each of them with other fibres similarly disposed;

they also blend near the intervertebral foramina with the short ligaments upon the sides of the column. Deeper still are other fibres thickening these expansions of the common ligament, and extending only from one bone to the next.

The last well-marked expansion is situated behind the intervertebral substance between the first two segments of the sacrum; below this spot the ligament becomes a slender, delicate, central cord, with only rudimentary expansions, but when it reaches the sacro-coccygeal joint it again becomes more pronounced, and helps to strengthen that joint as it does the several amphiarthrodial joints between the vertebræ. On the back of the coccyx it blends with other stronger ligamentous tissues.

In the cervical region the ligament rests flat upon and extends quite across the bodies of the vertebræ; in the dorsal and lumbar regions it is stretched over without resting upon the backs of the bodies of the vertebræ, from which it is separated by bloodvessels and some loose cellular tissue, which serves as a delicate periosteum for the bones where the ligament is not connected with them. At the foramen magnum and on the occipital bone it is closely united with the dura mater, which, however, can be dissected up from off it. Along the sacrum and at the coccyx the filum terminale becomes blended with it. Elsewhere a loose cellular membrane attaches the dura mater to the ligament.

The posterior common ligament checks undue flexion, and prevents displacement forwards of the vertebræ. By its great strength and breadth in the neck and its ascent to the cranium it helps to hold up the head upon the spinal column. In this it is assisted by the dura mater and the supra-spinous ligament. Its expansions over the joints of the bodies serve the same purpose within the spinal canal as the intervertebral ligaments serve on the exterior—viz., to strengthen the union of the intervertebral substances with the contiguous bodies of the vertebræ.

The Intervertebral or Short Vertebral Ligaments.—Along each side of the column, between the anterior and posterior common ligament, are numerous short fibres passing from the body of one vertebra to that of the next, and on this account they may be called intervertebral ligaments.

The more superficial fibres of these short ligaments are more or less vertical; those near the anterior common ligament being more so than those nearer the pedicles. The deepest and shortest fibres pass from the lower edge of the vertical surface of one vertebra to near the upper edge of the vertical surface of the next. As they pass over the intervertebral substances many of these fibres decussate with one another, so that they may be called *crucial* from their arrangement. They are closely united to the intervertebral substances, and it is no doubt owing to this, and to the fact that these short ligaments are connected with the deep surface and more central portion of the anterior common ligament, that the latter is usually described as being more firmly fixed to the edges of the bodies and to the intervertebral substances than to the central concave part of the vertical surface of the bodies.

In the cervical region the fibres of these short ligaments are more scattered and less well marked; they are covered by the longus colli muscle, the tendinous slips of which can hardly be separated from them.

In the dorsal region they overlie the fibres of the stellate ligament, and in the lumbar they even radiate towards the transverse processes (as the stellate ligament does towards the rib), from the vertebra and substance above, as well as from the vertebra to which the transverse process belongs. In the case of the fourth and fifth lumbar vertebræ, the fibres thus passing to the transverse process are very strongly marked, and some of them are continued into the lumbo-iliac ligament. Much the same arrangement is to be seen on the front of the sacrum, where the strong fibres of the periosteum radiate towards the ribs of bone between the anterior sacral foramina.

At the intervertebral foramina in each region of the column these short ligaments blend with the expanded areas of the posterior common ligament, while in front, as stated above, they are connected with the anterior common ligament. Thus is formed a complete casing of ligamentous tissue around each amphiarthrodial joint between the bodies of the vertebræ.

The intervertebral or short vertebral ligaments limit movement in every direction, and assist the intervertebral substances in binding the bodies firmly together.

The great strength given to the spinal column by these ligaments, and the extent to which they limit the yielding of the intervertebral substances and the movements of the vertebræ,

can be appreciated by noticing the increased pliability of a portion of the column after these ligaments have been removed by dissection.

Ligaments and Joints connecting the Posterior part of the Spine.

The posterior portion of the spinal column consists of the arches with their outstanding processes, and of the ligaments connecting them. We shall consider first the laminæ of the arches; secondly, the articular processes; thirdly, the non-articular processes; and fourthly, the ligaments of these several parts in the same order.

THE OSSEOUS STRUCTURES.—*The Laminæ* vary in shape and dimensions in the different regions. Those of the last dorsal and the upper three lumbar vertebræ are the shortest of all from side to side, and very deep from above downwards. Those of the fourth lumbar vertebra are longer from side to side, and somewhat deeper than those of the bones immediately above, this difference being due to the more lateral position of the inferior articulating processes of the fourth lumbar, which are as widely apart from each other as the superior of the same bone.

The laminæ of the fifth lumbar are still longer from side to side—indeed they are the longest in the column; they are also much shallower than either those in the dorsal or in the rest of the lumbar region. They are longer at the lower (sacral) border than above, owing to the greater width between the inferior than between the superior articular processes.

Excepting along the middle line, immediately beneath the roots of the spinous processes, there is no interval between the laminæ of any of the lumbar vertebræ (except the fourth and fifth) appreciable from the outside—*i.e.*, behind. This interlaminar interval along the middle line is the result partly of the horizontal direction of the spinous processes, and partly of the considerable downward and upward prolongation of the outer end of the laminæ into the inferior and superior articulating processes respectively.

In the dorsal region the laminæ are nearly square, flattened plates, with their surfaces forwards and backwards, and borders above and below. Owing to the different direction of the articulating processes, and to the downward inclination of the spinous processes one over the other, there is no appreciable space between the laminæ even along the median line. In

this way therefore the spinal canal is entirely shielded by bone in the region where its contents are most exposed to injury owing to the backward curve of the column.

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In all the regions of the column the laminæ of each vertebra are marked by the attachment of two ligamenta subflava. Along the upper edge, and extending a little way along the posterior surface near the middle line, is a rough ridge (often very uneven) to which the lower border of the ligament above is attached. This is best marked in the middle and lower parts of the dorsal region, where there is often a distinct horseshoe-shaped roughness, the concavity of which is upwards on the posterior surface of the laminæ, between the articular facets.

projections in the cervical and lumbar regions, and produce those gentle curves in the line of the column which have led to its being called " the line of beauty" in all ages.

The concavity forwards of the dorsal region is almost entirely due to the shape of the bodies of the vertebræ, but is somewhat increased by the intervertebral substances.

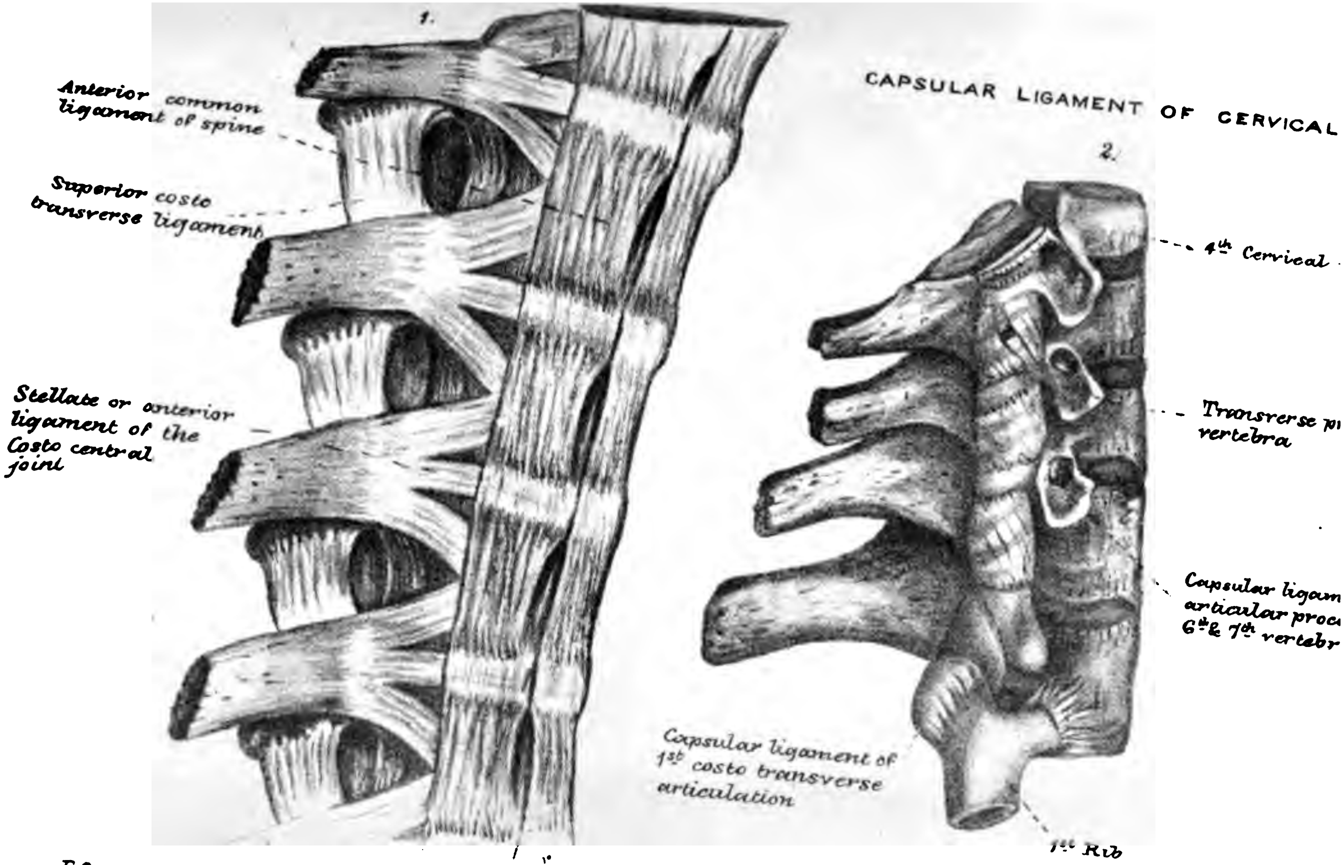
THE LIGAMENTS.—The intervertebral substances are closely bound by the ligaments which pass over them and the bodies of the vertebræ; and in the dorsal region, the inter-articular ligaments of the heads of the ribs are also firmly attached to the intervertebral substances.

By means of the intervertebral substances alone the vertebræ are united together very firmly, in much the same way as the several parts of the pelvis are by their symphysial cartilages; but the column so constructed is too supple and flexible, so that the union of the several segments requires to be further bound together by long, and short immediate ligaments. These ligaments are the anterior and posterior common vertebral, and the short intervertebral ligaments.

Further, the stellate ligaments of the costo-vertebral joints, though not ligaments properly speaking of the spinal column, yet give strength to it by binding two vertebræ and the intervening substance to the same rib or lateral buttress.

The Anterior Common Vertebral Ligament extends, as a very distinct longitudinal band, from the second cervical vertebra to the sacrum. At the middle of the sacrum it becomes gradually lost in the periosteum of that bone, but is again distinguishable as a ligament in front of the sacro-coccygeal articulation.

At its upper extremity it is continuous with the narrow central portion of the anterior atlo-axoidean ligament, which, like it, is firmly connected with the front of the body of the axis. At first narrow and pointed, it gradually widens as it descends, until it measures from one and three-quarters to two inches at the fifth lumbar vertebra. It is thickest in the dorsal region, and thicker in the lumbar than in the cervical region. Its structure is bright pearly white and glistening, with straight and well-defined borders. These borders are particularly well marked in the dorsal region, where, over the bodies of the vertebræ, the finger-nail can be inserted beneath them. The ligament can be detached from end to end as a ribbon-like


1.
Anterior common ligament of spine
Superior costo transverse ligament
Stellate or anterior ligament of the Costo central joint
2.
4th Cervical
Transverse p
vertebra
Capsular ligam
articular proc
6th & 7th vertebr
Capsular ligament of 1st costo transverse articulation
1st Rib
E. Steel

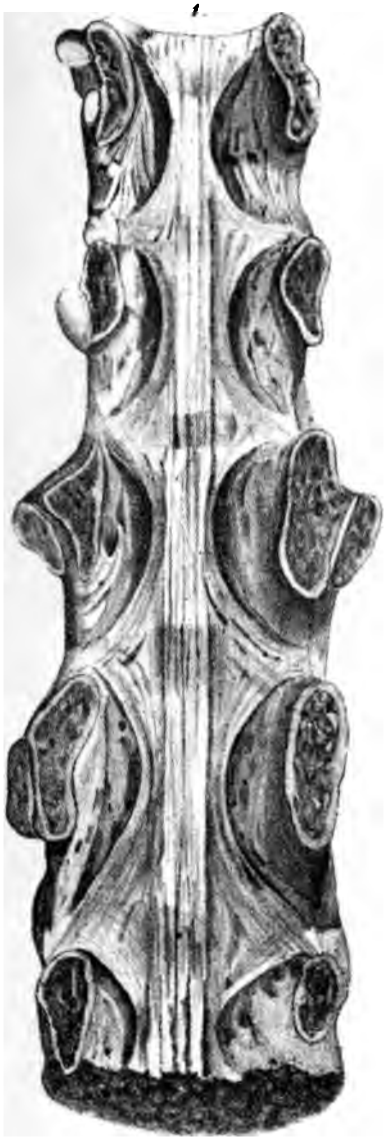
CAPSULAR LIGAMENT OF CERVICAL

POSTERIOR COMMON LIGAMENTS

PLATE VIII.

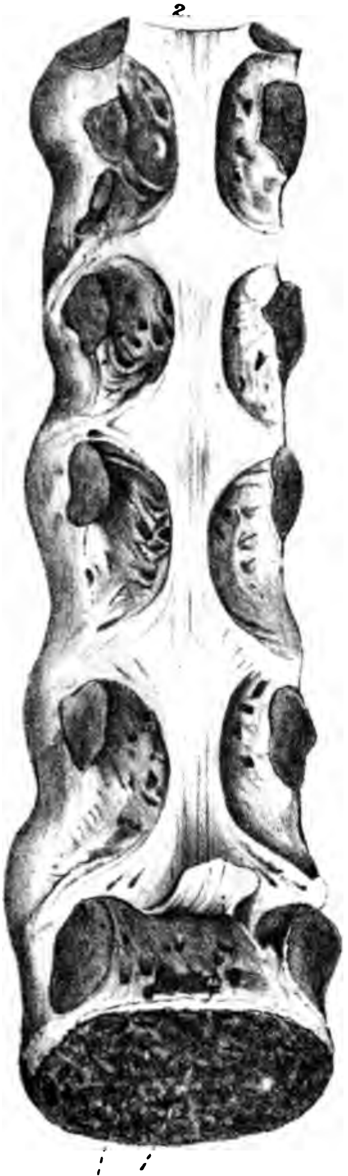
IN THE LOWER HALF OF DORSAL REGION

1.



IN THE LUMBAR REGION.

2.



Lig: turned up showing large foramina for blood vessels in the back of the bone

A Hensman del. ad. nat.

West Newman & Co lith

band. It is firmly connected with the bodies of the vertebræ. Its superficial fibres extend over several, its deeper over only two or three bones. It is strengthened in the cervical region by the tendinous fibres of the prævertebral muscles, and in the lumbar region by the crura of the diaphragm.

The anterior common ligaments prevent undue backward movement of the vertebræ—*i.e.*, over-extension of the spine.

The Posterior Common Vertebral Ligament extends from the occipital bone to the coccyx. It is wider above than below, and at its commencement has a broad attachment to the cranial surface of the basilar portion of the occipital bone. As it passes over the back of the bodies and intervertebral substances, it varies somewhat in the different regions of the column. Throughout the cervical portion it is of nearly uniform width, although on the level of the intervertebral substances it retains the same thickness somewhat further outwards on each side than over the bodies of the bones, and it is continuous with the short intervertebral ligaments at the intervertebral foramina.

In the dorsal and lumbar regions it has distinctly dentated borders, being broader over the intervertebral substances and the edges of the bones than over the middle of the bodies of the vertebræ. In the latter situations, where its close attachment to the bone is not requisite for strength, and where numerous bloodvessels pass into and out of the osseous substance, the ligament is a narrow band along the median line. These narrow portions consist of longitudinal fibres, some of which are superficial and pass over several vertebræ, and others are deeper and extend only from one vertebra to the next but one below. The broader portions or expansions of the ligament are formed by oblique fibres, which, springing from the lateral surface of the bodies near the intervertebral foramina, take a curved course downwards and backwards over an intervertebral substance, and reach the narrow portion of the ligament on the centre of the vertebra next below. They again diverge outwards to pass over the next succeeding intervertebral substance, and end on the lateral aspect of the body of the vertebra beyond. The same fibres therefore are in connexion with the bodies of three vertebræ and two intervertebral substances—*i.e.*, two amphiarthrodial joints; they enter into two expansions and decussate in each of them with other fibres similarly disposed;

can be appreciated by noticing the increased pliability of a portion of the column after these ligaments have been removed by dissection.

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fifth, the processes again stand somewhat out from behind the bodies, and are seen from in front of the column. Thus, while *all* the facets at which movements occur between the occiput and atlas, and atlas and axis, are in the same transverse vertical plane, or nearly so; the articular processes of the dorsal and lumbar vertebræ, with the exception of the fourth and fifth lumbar, are in vertical planes more and more behind the posterior border of the bodies of the same bones according as they are situated lower in the column.

To this difference in the relative position of the articular processes is also due the *apparently* greater width of the cervical bodies as compared with the upper dorsal; the greater size of the spinal or vertebral canal in the cervical region; and the greater width of the vertebral groove. This is easily understood, for where the articular processes project most beyond the lateral lines of the bodies of the vertebræ there the laminæ are necessarily widest, and the space on each side of the spinous process between it and the articular processes is the greatest. Movement also is most free at those parts of the column where the bodies and articular facets are most nearly in the same transverse plane.

THE NON-ARTICULAR PROCESSES.—The spinous processes vary in the several regions. In the cervical, they are nearly horizontal, and (excluding the atlas and the seventh vertebra) are bifid. Those of the third and fourth are short; that of the axis is merely rudimentary; that of the seventh is long, broad, and tuberculated.

In the dorsal region, as low as the ninth dorsal vertebra, they are long, prismatic, inclined downwards over one another like the tiles on a roof; and tuberculated at their extremity. Their downward inclination prevents any undue projection in that part of the column which has its convexity backwards.

The spinous processes of the tenth, eleventh, and twelfth dorsal, and those of the lumbar vertebræ, are broad, thick, long, and horizontal in direction. The largest of all the spinous processes are those belonging to the first three lumbar vertebræ. That of the fifth lumbar is altogether smaller than the rest in this region.

Thus we notice that where movement is free the spinous processes are nearly horizontal.

The Transverse Processes.—In the cervical region there are two roots to each process—*one*, which springs from the side of the body, and the lateral lip of the upper articular disc of the body; and the *other* from the neural arch between the superior and inferior articular processes. The anterior root is the larger except in the case of the seventh cervical. The two roots are united at their outer ends, and, together with the pedicle between them, enclose the foramen for the vertebral artery. It is hardly correct therefore to describe, as is commonly done, the cervical transverse processes as being pierced at their base by the vertebral foramen. Between the foramen and the tip of the process the upper surface of the transverse process is deeply channelled for the passage of the cervical spinal nerves. Each process is somewhat curved downwards, and projects slightly forwards as well as outwards. They thus slightly overhang in front the capsular ligaments and the articular processes.

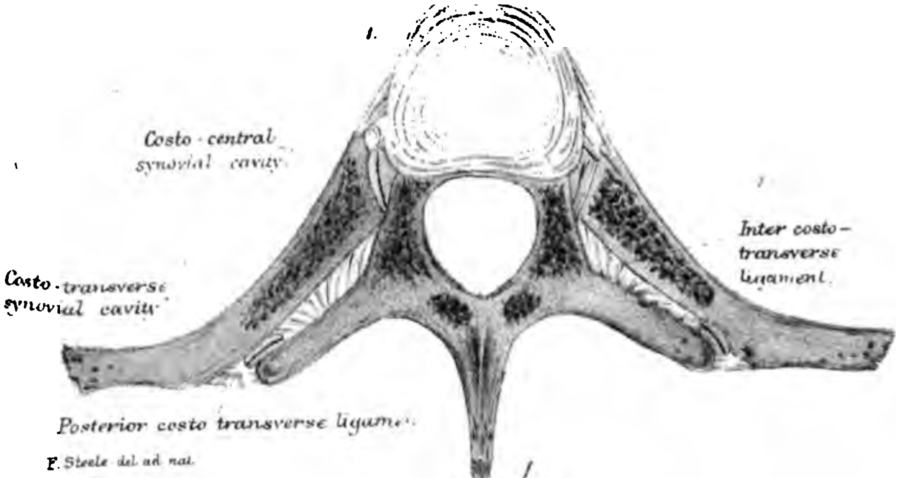
In the dorsal region, with the exception of the eleventh and twelfth, the processes are large and long. They project backwards as well as outwards, are tuberculated at their extremities, and are marked by facets for the tubercles of the ribs. They arise by only one root, which is connected with the neural arch between the superior and inferior articular processes. The capsular ligaments of two joints are partly attached to each process—that of the upper one to the upper and back part, that of the lower to the anterior and lower surface of the base of the process. The eleventh and twelfth dorsal vertebræ have stunted rudimentary processes, which indeed are generally only represented by three partially amalgamated tubercles. These tubercles become differentiated in the lumbar region, and are known as the accessory transverse and mamillary processes. In the lumbar region the transverse processes vary with each vertebra: those of the upper four are horizontal, and spring, like the dorsal, simply from the neural arch between the upper and lower articular processes, from which, however, they are separated by a considerable interval.

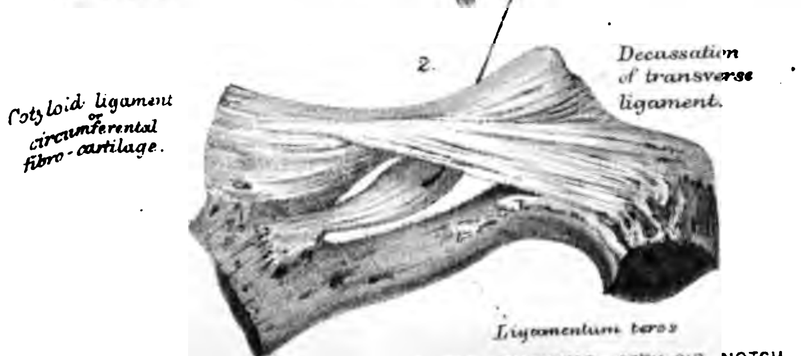
This origin of the lumbar transverse processes is strongly opposed to the opinion held by some anatomists, that they are homologous with ribs. If the anterior roots of the cervical processes are rightly considered to be the homologues of ribs, it is difficult to see how the processes of the four upper lumbar vertebræ, which are equivalent to the posterior roots of the cervical transverse processes, have any such homology. That of the fifth lumbar is very broad and massive, and is inclined backwards, outwards, and slightly upwards. It springs, like the cervical transverse processes, from the side of the body as well as from the neural arch, only, unlike the cervical processes, it has no large foramen between its roots, but only a little hole or two for small vessels: hence the process seems to be massed together both with the pedicle and with the side of the body of the bone. Great strength is given to this vertebra by the consolidation of these parts, while at the same time we see in it the commencement of an arrangement which attains its fulness in the construction of the sacrum.

In length the transverse processes of the five lumbar vertebræ usually stand to one another thus: the third is the longest, the second next, and then the first, fourth, and fifth, in succession. They are each slighter, and the third is often longer than the corresponding dorsal processes.

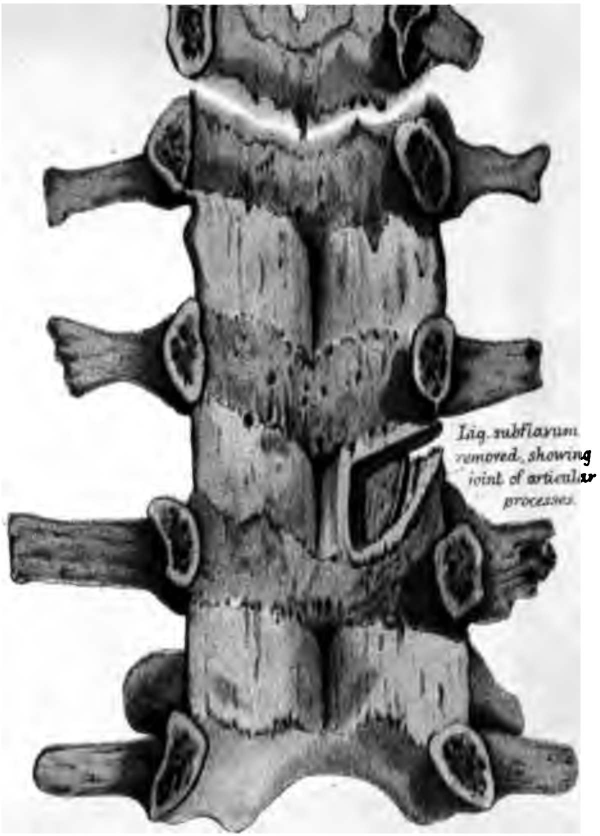
LIGAMENTS CONNECTING THE LAMINÆ AND ARTICULAR PROCESSES.—*The ligamentum subflavum* is a shallow plate of closely woven yellow elastic tissue, interposed between the arches of two adjacent vertebræ. The first plate connects the axis with the third cervical vertebra, and the last connects the fifth lumbar with the first segment of the sacrum. Each ligament extends from the inner and posterior edge of the intervertebral foramen on one side to the corresponding point on the opposite; and thus besides closing the interlaminar spaces and acting as a bond of union for the vertebral arches, they each form part of two capsular ligaments. They are convex from above downwards in front, but concave from side to side, making a more decided transverse curve than the arches of the vertebræ between which they are placed. This concavity is more marked in the dorsal and still more in the lumbar region than in the cervical, as they extend in the former regions a short distance between the roots of the spinous processes where they blend with the interspinous ligaments. There is therefore in the dorsal and lumbar regions no actual separation of the ligament into two lateral halves, although in the latter there appears at first sight to be such, owing to the decided folding of the ligament upon itself, in the middle line, whereby the inner surface is in apposition with itself, for a short distance as the ligament projects back-

PLATE IX.


1.
Costo-central synovial cavity.
Costo-transverse synovial cavity.
Inter costo-transverse ligament.
Posterior costo transverse ligam…
F. Steele del. ad nat.


2.
Decussation of transverse ligament.
Cotyloid ligament or circumferental fibro-cartilage.
Ligamentum teres

PORTION OF ISCHIUM & PUBIS SHOWING COTYLOID NOTCH AND LIGAMENTUM TERES ATTACHED TO ISCHIUM OUTSIDE THE CAVITY.


Lig. subflavum removed, showing joint of articular processes.

wards a little way between the roots of the spinous processes. This folding and backward extension give the appearance of a median sulcus when seen from the front.

In the dorsal region there is only a median depression, not amounting to a sulcus. In the cervical region, where the spinous processes are bifid, there is a median fissure in the yellow ligament, which is filled up by fibro-areolar tissue, but there is no actual interval between the two halves, only an interruption in the nature of its structure.

To the higher of the two arches between which it extends each ligamentum subflavum is attached on the inner or anterior surface of the lamina, and close to the inner edge of the inferior articulating processes, along which it ascends on each side of the middle line, from the root of the spinous process. Owing to the more antero-lateral situation of the articular processes of the cervical vertebræ, the yellow ligament does not enter quite so freely into the formation of the capsular ligaments of this region, as of those of the dorsal and lumbar.

To the lower of the two arches the ligament is attached on the upper edge of the lamina, descending in the middle line, especially in the dorsal region, over the outer or posterior surface; laterally it is attached to the inner or anterior surface of the arch close to the inner border of the superior articulating processes.

The ligaments are thickest and strongest in the lumbar region; narrow, but strong, in the dorsal; and broader, thinner, and more membranous in the cervical region.

There are, as stated above, well marked rough ridges on the arches of the dried vertebræ, showing the attachments of these ligaments; those of the superior attachments are stronger than those of the inferior. The dorsal vertebræ show the strongest markings; the lumbar are also strongly impressed by the ligaments, but the cervical are much less so.

Uses of the Ligamenta Subflava.—It is invariably stated that the ligamenta subflava are stretched during flexion forwards of the spine, and that by virtue of their elasticity they assist the muscles in bringing the column back again to, and in retaining it in, the erect posture. A careful examination of the ligament in different parts of the column convinces one (1) that it is stretched throughout on bending the spine forwards; (2) that the right half of the ligaments is stretched on *bending* the column to the left, and the left half on *bending* the column to the right side; and (3) that the right portions of the ligaments are stretched on *twisting* the left side of the body forwards, and the left portions on twisting the right side forward.

A good idea may be obtained of the elasticity of these ligaments, after separating the arches from the bodies of the cleanly dissected spine, by putting them on stretch between the two hands like a piece of elastic. In this way I have increased the length of the lumbar portion of the column (consisting of the arches of five vertebræ and four ligamenta subflava) half an inch, which is equivalent to one-eighth of an inch for each ligamentum subflavum. This fact I had ascertained long before seeing Dr. Sayre's demonstrations of his excellent method of treating spinal diseases by the application of plaster bandages after extending the spine by compound pulleys; and if we bear in mind that there are twenty-three yellow ligaments in the column, and that the intervertebral substances are like springs compressed, we can understand how three-quarters of an inch, or even an inch and three-quarters, in stature might be added to the height of the patient, by means of extension, without any of the important adhesions around the diseased parts being destroyed.

It must be borne in mind, however, that in the living subject the intervertebral substances are tightly covered over by inelastic white fibrous ligaments—viz., the anterior and posterior common vertebral and intervertebral ligaments—and that the ligamenta subflava cannot be stretched so much before as after the removal of these encasing ligaments. I cannot therefore concur in the view that the yellow ligaments assist the muscles in restoring and preserving the upright position. The degree to which the ligaments are stretched by ordinary forward flexion of the human body must be very slight, so that the resiliency of their structure is brought insufficiently into play for the purpose named. Moreover, the central portions of the intervertebral substances (elastic *springs* much nearer to, indeed in the very axis of, movement) would by their elasticity restore the bones after they have been disturbed from their position of rest. Nor is it likely that these ligaments offer any material resistance to the continual forward pull of the viscera and other soft parts of the body which are placed in front of the column. Such a continual drag upon elastic structures would soon wear out their elasticity and render them inert. Besides, we know that when the muscles of the back become enfeebled, as in illness, or the intervertebral substances ossify, as in old age, the column curves forwards in spite of these ligaments, so as to assume, in extreme cases, the form illustrated in Diagram I. *a*, page 71. This figure represents the dry bones of the human spinal column, with their bodies and articular facets in apposition, but without their intervertebral substances. In the Hunterian Museum there is a column thus curved, owing to ossification of the intervertebral substances and ankylosis of the bodies of the vertebræ by means of bridges of bone thrown out from their edges. Nor have the ligamenta subflava any power to preserve the upright position in advancing age when the intervertebral substances are shrinking, and as a consequence the stature is diminishing and the arch of the back progressing.

To counteract the effects of the forward disposition of the viscera on the spine there are several provisions. In those parts of the trunk in which the largest viscera are placed, the column itself curves backwards; the ribs also curve considerably back before they arch forwards, and thereby allow of some portions of the viscera being placed at the sides of, and even on a posterior plane to, the column.

The position of the scapula upon the posterior surfaces of the most backward projecting ribs throws back the weight of the shoulders, while powerful and extensive muscles pass to the upper extremity from the whole series of spinous processes between the occiput and coccyx.

If then the ligamenta subflava are not required, and cannot act to restore and preserve the erect posture, what are the uses of these wonderful little structures?

1. They complete the roofing in of the vertebral canal in the interlaminar spaces, and yet at the same time they permit constant variations in the width of the interspaces—variations required by the shifting of the articulating processes upon one another, and therefore of the laminæ in relation to one another.

2. They restore the articulating surfaces to their normal position with respect to each other after they have been disturbed therefrom by muscular action, either in antero-posterior, lateral, or rotatory movements.

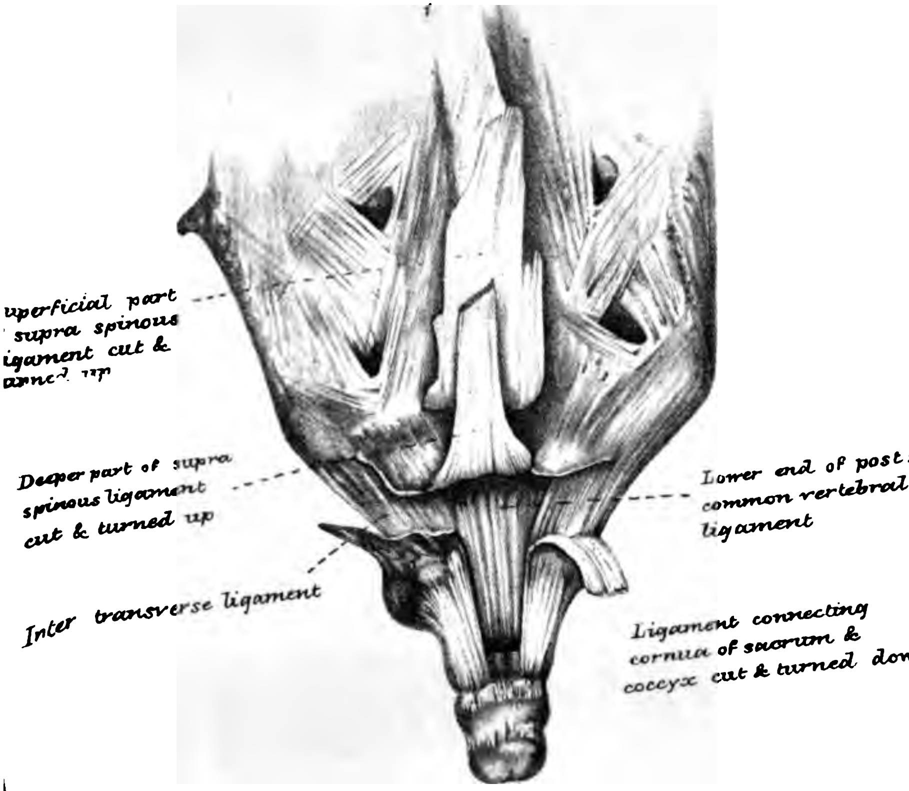
This normal position of the articular surfaces in the cervical and dorsal vertebræ is one of almost complete apposition; but in the lumbar region, the superior processes are so much wider apart than the inferior of the vertebræ next above with which they articulate, that complete apposition is not possible on both sides at the same time.

3. By forming the inner portion of the capsule of the articulating processes they prevent it from being nipped between the moving surfaces. Elsewhere in the body we find muscles connected with capsular ligaments for this purpose, and even here, on the posterior and outer sides of these little joints, there are small muscles connected with the inelastic part of the capsule. In the vertebral canal, however, muscles and muscular action would be incompatible with the nerve structures against which they would be placed. Here we find the capsules completed by elastic tissue, which can protect itself through its own elasticity, from being plicated and caught between the facets of the moving bones. In the cervical region, where these facets are thrown considerably beyond the sides of the bodies of the vertebræ, and where the capsular ligaments are connected with muscles in front as well as on the outer side and behind, the ligamenta subflava do not extend so far in front of the joints as in the other regions of the spine.

The Capsular Ligaments are composed partly of elastic yellow tissue—the ligamenta subflava—and partly of white fibrous tissue. They bind together the articular processes of the vertebræ, and are lined by a distinct synovial membrane. In the cervical region, only the inner side of the capsule is formed by the yellow elastic ligament, whereas in the dorsal and lumbar regions, not only its inner side, but the anterior portion up as far as the margin of the intervertebral foramen, is formed by it. The portions composed of the inelastic white fibrous tissue—ordinary ligamentous tissue—consist of short, well-marked fibres, which in the cervical vertebræ extend obliquely downwards and forwards over the joints between the articular and posterior transverse processes of two contiguous vertebræ; in the dorsal region the fibres are shorter and vertical in direction, and are attached to the bases of the transverse processes in the manner referred to in the description of those parts of the vertebræ; in the lumbar region they are obliquely

LIGAMENTS CONNECTING SACRUM & COCCYX POSTERIORLY

1



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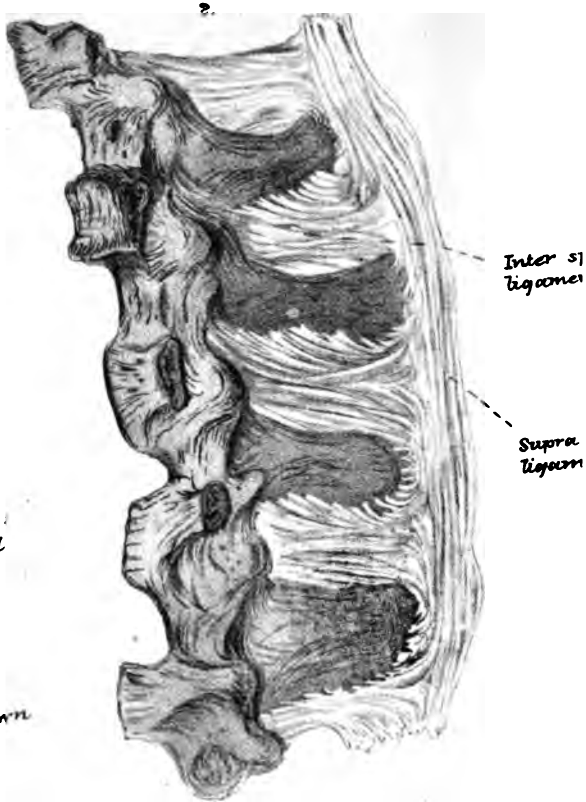
SUPRA & INTER-SPINOUS LIGAM
IN LUMBAR REGION

2.



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transverse in direction, and pass over the joints from one articular process to the other.

In the cervical and lumbar regions a very considerable portion of each capsule can be seen after removing the tissues in the intervertebral foramina and the muscles of the neck or loin; but in the dorsal region very little of them can be seen from outside, owing to the ribs masking them on the outer side and, as a result of the overlapping of the articular processes behind, to the consequent shortness of the fibres of the capsules. After removing the arches from the bodies of the vertebræ, the joints can be laid open in front by cutting away the ligamenta subflava as shown in the plate of these ligaments.

The capsular ligaments in the cervical region are the most loose, those in the lumbar the next so, and those in the dorsal the least. This is in accordance with the different degrees of movement permitted to the vertebræ in the three regions.

SYNOVIAL MEMBRANE.—The capsular ligament of each pair of articular processes has a distinct synovial lining.

THE LIGAMENTS CONNECTING THE NON-ARTICULAR (THE SPINOUS AND TRANSVERSE) PROCESSES.—These processes give origin and insertion to the muscles of the spine, but do not directly add to the strength or security of the column. The ligaments which connect these processes are chiefly intermuscular septa or aponeurotic structures, and are insignificant as ligamentous structures proper—that is, as checks to movements or as media of union between bones.

The ligaments of the spinous processes are stronger and better marked than those of the transverse processes.

The Supra-spinous Ligament extends along the tips of the spines of the lumbar and dorsal vertebræ as a well-marked band of longitudinal fibres, which are continuous at the sides with the aponeurotic structures of the back. It is thicker in the lumbar region than in the dorsal. Its more superficial fibres are much longer than the deeper. Above it is continuous with the *ligamentum nuchæ* which reaches to the occiput; a thin tendinous expansion passes between the tips of the cervical spines and the deep aspect of the ligamentum nuchæ. Below the supra-spinous ligament passes over the sacrum to the coccyx, and ends on the back of the latter. It adds very materially to the security of the sacro-coccygeal joint, and covers in the spinal canal, where for the want of the laminæ of the sacrum and coccyx it would otherwise be exposed.

The *interspinous ligaments* are membranous structures, which extend between the spines of adjacent vertebræ from their roots to their tips. They are connected at the roots of the spine with the ligamenta subflava, and near the tips with the supra-spinous ligament. They are best marked in the lumbar region, and are ill defined in the neck. Their fibres do not extend directly from spine to spine, but run obliquely from the root of one towards the tip of the other. They form septa along the middle line between the muscles of the two sides of the back.

Ligaments of the Transverse Process are barely worthy of the name. In the cervical region they can hardly be said to exist at all, and are never anything more than a few fibres between the apices of the processes.

In the dorsal region they form small round bundles, which extend somewhat obliquely downwards and outwards near the tips of the processes. They are best seen from behind. In the lumbar region they are thin membranous bands, quite incapable of acting as bands of union.

ARTERIES OF THE SPINAL COLUMN.—Numerous small arteries are given off to the front, side and back of the bodies of the vertebræ from the vertebral artery; and the ascending cervical branch of the inferior thyroid artery in the neck; from the intercostal arteries in the dorsal region; and from the last dorsal and lumbar arteries in the loins. On the front of the column some of these little vessels pass beneath the sharp edge of the anterior common vertebral ligament to reach the vertical surface of the bodies of the vertebræ, which they penetrate; on the sides other small twigs enter the bones by passing between the fibres of the short intervertebral ligaments; and at the back branches are given off from the anastomosing arches within the spinal canal to enter the bodies of the vertebræ beneath the posterior common ligament. Blood is conveyed by these vessels over the surfaces of the intervertebral substances; and to the articular discs of the vertebræ by the vessels which ascend and descend through the cancellous tissue of the bodies.

To the capsules of the articular processes branches are given off, in the cervical region from the deep cervical of the superior intercostal, and deep cervical branch of the occipital arteries; in the back from the dorsal branches of the intercostal, and in the loins from the dorsal branches of the lumbar arteries. They supply the muscles in the vertebral groove, and send one or more minute twigs to ramify over the back of the capsular ligaments, which they penetrate to reach the synovial lining of the joints.

A further blood supply is derived from the "*spinal branches*" of the vertebral and ascending cervical arteries in the neck, and from the spinal subdivision of the dorsal branches of the intercostal and lumbar arteries. After passing into the spinal canal through the intervertebral foramina, these *spinal branches* break up in the soft fat which surrounds the sheath of the nerve-roots into three divisions; one runs along the nerve-root to the cord and its membranes, another goes forward to the backs of the bodies of the vertebræ, and the third backwards to the lamina of the vertebra. This last vessel passes over the joint of the articular processes, and gives one or two minute twigs to the capsule, which they penetrate to reach the synovial membrane.

I have never seen anything like an arterial zone around the margin of the articular cartilages of these joints, as is formed by the arteries of the larger articulations.

NERVES.—Filaments are supplied to the articulations by the spinal nerves in each region.

MOVEMENTS OF THE SPINAL COLUMN.—The spinal column is so formed of a number of bones and intervertebral substances arranged in curves, and bound together by elastic and inelastic ligaments, as to serve many purposes. It is the axis of the skeleton, upon it the brain-case is supported, and with it the walls of the cavities of the trunk, and also the limbs, are connected. As a fixed column it is capable of bearing great weight, and through the elastic intervertebral substances, of resisting, and breaking the transmission of, shocks. Moreover it is flexible, and therefore capable of movement. Now the range of movements of the spinal column as a whole is very considerable, but the movements between any two of the vertebræ are slight, so that motions of the spine take place without any change in the shape of the column, and without any marked disturbance in the relative position of the vertebræ. It is to the intervertebral substances that these movements are owing; and it is about the central semi-fluid and tightly compressed part of these substances, which forms an elastic pivot or ball upon which the middle of the bodies of the vertebræ rest, that these movements occur. Hence this semi-fluid central cushion is most marked in those regions of the spine where movement is most free. The amount of movement is everywhere *limited* by the common vertebral ligaments; but it depends in part also upon the width of the vertebral bodies, as well as upon their contiguity—*i.e.*, upon the thickness of the intervertebral substances; for it is evident that, given the same dimensions of the elastic semi-fluid pivot, the movements will be most free where the area of the vertebral bodies is smallest. In the loins where, owing to the great superincumbent weight, the vertebral bodies are necessarily large and wide, the intervertebral substances are very deep, and thus prevent that restriction of the range of movements which the great size of the bones would otherwise produce. On the other hand, in the neck, where the intervertebral substances are much shallower, the area of the bodies of the vertebræ is small, so that the movements are on the whole as free as in the loins. In the back the vertebral bodies increase in area from above downwards, and are everywhere much larger than the bodies of the cervical vertebræ; while the intervertebral substances are less deep than those in the neck, with the exception of that between the axis and the third vertebra, which is shallower than any other in the column.

The soft pulpy portion of the intervertebral substance is then the centre of the movement of each vertebra—" the ball upon which the socket, formed by the contiguous surfaces of the vertebræ, revolves;" and it must be obvious that the movements of a column formed in this manner, of sockets and balls, must be of a *rolling* character, and may take place in any direction. While therefore, as has been stated, the amount of movement depends upon the depth of the intervertebral substances and the area of vertebral bodies, the direction of the movements must be regulated by some other means. It is one of the uses of the articular processes to limit the direction of motion, and their office further is to give steadiness to the column, and to assist the vertebral bodies in bearing the superincumbent weight. Were it not for these processes the column, instead of being a stationary one, endowed with the capacity of movement through the agency of voluntary muscles, would be a tottering one, which it would require the agency of the muscles to steady.

As then the vertebral bodies are free to deflect or incline in any direction upon their intervertebral substances within the limits permitted by the uniting ligaments, by their own shape and size, and by the shape and size of the intervertebral substances; the influence of the articular processes in limiting the direction of inclination will appear from a study of the various movements in the three regions of the spine.

In the neck, forward and backward movements are free, much more so than in the back, though less so than in the loins; but while the capacity of motion backwards from the upright position is greater than that of motion forwards in the neck, the reverse is the case in the loins. Flexion to either side is more free in the neck than in any other region.

Rotatory movements are also free in the neck, especially in the lower part of the region. There is but slight movement of any sort between the axis and third vertebra, owing chiefly to the shallowness of the intervertebral substance, and the great prolongation of the anterior lip of the lower surface of the axis, which checks forward flexion considerably.

The obliquity of the articulating surfaces of the cervical vertebræ permits of all these movements, but is especially favourable for extension or backward flexion. This increases the extension movement of the occipito-atloidean joints, and makes it still more easy to man—"erectos ad sidera tollere vultus"—to cast upward looks to heaven.

In the back, especially near its middle, antero-posterior flexion and extension are very slight. As the concavity of the curve of the column here is forwards, the flat and nearly vertical surfaces of the articular processes prevent anything like sliding in a curvilinear manner of the one set of processes over the sharp upper edges of the other, which would be necessary for forward flexion. These processes do not prevent a fair amount of lateral flexion, which, however, is less than it otherwise would be owing to the impediment offered by the ribs; whilst the outward inclination of the superior processes and the corresponding inward turn of the inferior, enable the latter to revolve slightly upon the former so as to permit a rotation of the bodies of the dorsal vertebræ around their own vertical axis. Indeed, in the upper part of the back rotation is very free.

In the loins the antero-posterior movements are very free, especially between the third and fourth, and fourth and fifth vertebræ, where the lumbar curve is sharpest; lateral inclination is also very free between these same vertebræ; and rotation also is permitted to a considerable extent and is often greatly increased after disease of the hip-joint, and in the rotatory-lateral curvature of the spine. It is stated on the authority of some excellent anatomists that the shape and position of the articular processes of the lumbar and lower two or three dorsal vertebræ are such as to prevent any rotation in these regions. This argument is supported by the statement that the horizontal motion of the arches and articulating processes necessary for any rotation of the bodies of the vertebræ around their own axis cannot take place owing to the manner in which the superior processes of one bone embrace the inferior processes of the next above. This objection would hold good if the one set of processes tightly embraced the other; in which case antero-posterior movement only would be possible in the loins, as lateral inclination equally with rotation would be impossible. But the fact is, as has been pointed out above, that the two sets of articular processes are not in contact with each other on both sides of the bodies at the same time, and that there is therefore always some space in which horizontal motion of the arches and processes can occur *round an axis drawn through the central part of the bodies and the semi-fluid nuclei of the intervertebral substances.*

It will be observed upon a careful study of the spinal column, that where the movements are most free the curves of the spine have their convexity forwards; also that their curves are due to the increased thickness in front of the intervertebral substances and not of the bodies; that there are no resisting bony walls surrounding cavities or viscera; that the viscera attached to the vertebræ are tubular and movable, not solid and fixed organs; further, that the muscular masses lodged in the vertebral groove are thicker and bulkier than elsewhere; that the spinal canal is larger, and the spinal cord, with its membranes and the spinal nerves, is less closely connected with the backs of the vertebral bodies; and finally, that the pedicles and the articular processes are more nearly on the same transverse level with the backs of the bodies of the vertebræ. These points are strikingly seen by comparing the cervical with the dorsal regions.

THE MUSCLES IN CONNEXION WITH THE SPINAL COLUMN.—As the spinal column is the centre of the skeleton, the basis of support for the head, trunk, and upper limbs, and the axis about which most of the movements take place, so is it the point of attachment of numerous muscles which extend to and act upon all these various parts of the skeleton, as well as of those which in their functions as well as connexions are confined to the vertebræ.

It will be convenient, therefore, in an enumeration of these muscles, to divide them into two principal groups—viz., the *extrinsic*, or those which pass from the column to some other part of the skeleton; and the *intrinsic*, which exclusively belong to the spine.

Extrinsic Muscles of the Spinal Column.—1. Those passing to and moving the head are the trapezius, the splenius capitis, the trachelo-mastoid, the complexus, and the short cranio-vertebral muscles—including the lateral and anterior recti.

2. Those passing to and moving the upper extremity are the trapezius, the latissimus dorsi, the levator anguli scapulæ, and the rhomboidei. Through the two former the upper limb is brought into connexion with the whole length of the vertebral column from the occiput to the pelvis.

3. Those passing to and acting on the thorax are the scaleni above; the diaphragm below; and the serratus superior and inferior, the levatores costarum, and the quadratus lumborum, behind. The transversalis abdominis attached to the lumbar vertebræ through its posterior aponeurosis is connected with the front of the thorax.

4. Those passing to and acting on the pelvis are the quadratus lumborum, the transversalis abdominis, and, when present, the psoas parvus.

5. There is one muscle extending from the lumbo-dorsal region to the lower extremity, and acting on the thigh—viz., the psoas magnus. It is no doubt partly owing to the action of this muscle in young life that the spinal column, which is nearly straight in the first year or two after birth, obtains its strong lumbar convex curve.

If now we exclude the short cranio-vertebral muscles as are attached to the ribs, but the cervicalis ascendens, though arising from the four or five higher ribs, is inserted into the posterior transverse processes of the fourth, fifth, and sixth cervical vertebræ.

Of the seven portions of the erector spinæ, therefore, two are altogether unconnected with the vertebræ—viz., (*a*) the sacro-lumbalis, which arises muscular from the posterior fifth of the crest of the ilium and is inserted into the lower six or seven ribs near their angles; and (*b*) the musculus accessorius, which both arises and is inserted by tendons attached near the angles of all the ribs; while a third—viz., the trachelo-mastoid, though it arises from the vertebræ, might both from its insertion and action be more fitly included under the extrinsic muscles of the spine. In classing these three parts of the great longitudinal dorsal muscle amongst the *intrinsic* muscles of the column, the convenience of following the common nomenclature of muscles, and not strict accuracy in the description of their attachments and uses, has been considered.

The name "erector spinæ" applied to this great muscular and tendinous mass, expresses only part of its action; it should be called "erector trunci et capitis;" for, besides extending the spine, it extends also the whole trunk through its extensive connexion with the ribs, and the head through its *trachelo-mastoid* prolongation.

The splenius colli turns the neck obliquely to one side; when both act together they pull the neck backwards—*i.e.*, extend it. The action of these posterior or post-vertebral intrinsic muscles varies according as those of only one side, or of the two sides, are in action at the same time. When those of the two sides act together they all tend to bend backwards the vertebral column and trunk; their power is enormous, and more or less of it is brought into play in the respiratory movements, as well as in almost all the great muscular efforts of the body and limbs. When those of one side act alone the extension is accompanied by lateral inclination or flexion, together with rotation. In the more decided rotatory movements certain of the muscles of one side will co-operate with others of the opposite. Thus in rotation of the upper part of the trunk to the *left*, not only will the splenius and the prolongations of the erector spinæ of the *left side* be brought into action, but the muscles of the opposite side, whose fibres take an upward and inward direction—viz., the semi-spinalis, the multifidus, and rotatores spinæ, will assist the former in their work. Indeed, stated in general terms, it may be said that those muscles on one side of the median plane of the column which pass from transverse processes to spines, rotate the vertebræ towards the opposite side, and are assisted in this action by the muscles on the opposite side which pass from spines to transverse processes.

The inter-spinales approximate the spinous processes between which they pass, and thus extend the part of the spinal column to which the muscles in action are attached.

The inter-transversales, when the muscles of the two sides act together, must assist in extending the column, for the transverse processes are behind the bodies of the vertebræ, and the muscles which pass between them must therefore tilt backwards the arches and extend the spine. When those of one side act alone the tendency must be for them to cause postero-lateral flexion, or inclination of the column towards their own side, as well as slightly backward.

The connexion of the quadratus lumborum with the tips of the transverse processes of the lumbar vertebræ resembles the attachments of the scalenus posticus muscle in the neck. It is of interest too, as furnishing a compensating means of support and strength to that part of the column which is devoid of lateral buttresses, such as the ribs, yet has to bear greater weight than the dorsal vertebræ. At the same time that it affords support it also provides an additional power for movement, and serves with the muscle of the opposite side to keep the lumbar portion of the column erect, and to extend it; while if one muscle acts alone it turns the lumbar vertebræ upon their axis, and inclines them to its own side, just as the scalenus posticus acts upon the cervical vertebræ.

The quadratus lumborum, like the sacro-lumbalis, acts also on the ribs, pulling them downwards, and thus assisting the lower serratus muscle to fix, as it were, the lower part of the thorax for the more advantageous action of the diaphragm.

It seems at first thought strange that, whereas the head is steadied and moved upon the spinal column, and the trunk is steadied, balanced, and moved upon the heads of the femora by muscles situated on all sides of the joints, the muscles which steady and move the several vertebræ are placed upon the posterior aspect only of the spinal column. But it must be observed that the weight of the viscera, of the head as well as of the trunk, tends to pull the body forwards—*i.e.*, to bend the spine; and that therefore the muscular power of the column in most positions is requisite, not *for* forward movements, but to *prevent* them; whilst for lateral and rotatory movements, more especially as the articular processes are behind the bodies of the vertebræ, the muscles are more advantageously situated as they are than they would be were they in front of the axis of the column.

There are some positions, however, in which the muscular force is required to be in front of the column, in order to effect the necessary movements; but in these cases other muscles, which have no connexion with the spine, come into action upon it through the trunk and upper limbs. For instance, in rising from the horizontal position, as after lying on one's back, or even in rising from a low-backed easy-chair, we first draw our head and neck forwards by such muscles as the sterno-cleido-mastoid, the longus colli, anterior recti, and scalenus anticus, and then we bend forwards the rest of our spinal column through the agency, not only of the psoas magnus, which is directly attached to the column, but also of the abdominal muscles which act on the sternum and ribs, and through them on the spine, and of the muscles of the upper limbs, which by fixing the shoulders enable the latissimus, trapezius, and rhomboids to act as it were from in front of the column. Moreover, in forcible and violent respiratory movements, the serratus magnus is capable of moving the bodies of the upper eight dorsal vertebræ upon one another in the following manner:—The scapula, being itself attached to the spinal column by the rhomboids and the trapezius, has attached to its base the serratus magnus, and these two sets of muscles may be practically regarded, so far as certain movements of the spinal column are concerned, as one set with the scapula interposed in their substance. Now when the scapula is fixed and drawn back by the trapezius and rhomboids, the serratus magnus acts with greater effect upon the ribs to which it is attached; but the ribs may be regarded as levers, the long arms of which are curved towards the sternum, while the short arms are passing to and resting against the transverse processes and bodies of the vertebræ, so that when the long arms are acted upon by the muscle the short arms by their pressure upon the vertebræ cause them to rotate. Unequal action of this kind on the two sides of the body is doubtless one of the causes of lateral curvature of the spine, a deformity which is due to irregular muscular contraction, and not to organic changes in the vertebral bodies or intervertebral substances.

In connexion with the attachment of muscles to the spine, mention must not be omitted of the so-called *dorsal or lumbar fascia or aponeurosis*, which in the lumbar region is attached to the vertebræ in three planes. The anterior, opposite the outer border of the erector spinæ muscle, is continuous with the posterior aponeurosis of the transversalis abdominis muscle, and passes in front of the quadratus lumborum muscle to the roots of the lumbar transverse processes; at its upper part it is connected with the last rib, and forms the ligamentum arcuatum externum of the diaphragm.

The middle layer passes between the quadratus and erector spinæ to be attached to the tips of the lumbar transverse processes.

The posterior layer, which is sometimes distinguished by the name *vertebral aponeurosis*, is attached to the spines of the dorsal, lumbar, and sacral vertebræ; above it separates the muscles which belong to the shoulder and arm from those belonging to the head and spine, and extends upwards beyond the superior serratus muscle to the neck; below it covers in the vertebral groove of the sacrum, and is blended with the superior expansion of the great sciatic ligament. Through the connexion of the vertebral aponeurosis with this ligament, and of this ligament with the tendons of the hamstring muscles, the traction exerted by the hamstring muscles is extended to the spines of the lumbar and dorsal vertebræ. And as this aponeurosis is penetrated by branches of the same nerves which supply the erector muscles of the spine, and as traction on the aponeurosis must necessarily irritate these nerves, we see how the erector spinæ is brought into associated action with the hamstring muscles, so that they at once set about to elevate the head and upper end of the bent trunk as soon as the hamstrings commence to extend the pelvis on the thigh bones.

CHAPTER VI.

THE LIGAMENTS AND JOINTS WHICH CONNECT THE VERTEBRAL COLUMN WITH THE PELVIS ;

Or the Sacro-lumbar, Sacro-vertebral, or Lumbo-Pelvic Union.

THE vertebral column is united with the pelvis at what is called the sacro-lumbar or lumbo-pelvic union. Like the connection of the several segments of the column with one another, it consists of an amphiarthrodial joint between the bodies, and of a pair of arthrodial joints between the articular processes of the bones. Entering into this union, besides the sacro-lumbar joints and their own *intimate* ligaments, there are also the *accessory* or lumbo-pelvic ligaments which connect the processes of the fifth lumbar vertebra with the sacrum and ilium.

The bones which enter into the sacro-lumbar articulations are the fifth lumbar vertebra by the under surface of its body and its inferior articulating processes, and the sacrum by its base and superior articulating processes.

THE FIFTH LUMBAR VERTEBRA.—*The centrum or body,* though somewhat wider in every direction than the bodies of the vertebræ above it, is not so deep as they are, and especially not as the body of the fourth. The under surface which is connected through the intervertebral substance with the facet on the base of the sacrum measures two and a quarter inches wide, by nearly one and a quarter inches from before backwards ; it is deeper in front than behind by about a quarter of an inch. When looked at from in front it appears much wider in the upper three-quarters of its depth than do the bones above. This is on account of the strong transverse processes which arise from the sides of the body, whereas the transverse processes of the rest of the lumbar vertebræ spring from the points of meeting of the pedicle and lamina.

The inferior articulating processes are nearly one inch and a half apart, and are irregularly circular in outline; they are larger, much less convex, and are directed more forwards and much less outwards than the corresponding processes of the other lumbar vertebræ. On this account somewhat more rotation round a vertical axis is permitted between them and the sacrum than is possible between the lumbar vertebræ themselves.

The transverse processes are shorter, but thicker and stronger, than the transverse processes of any of the other lumbar vertebræ. They are curved somewhat upwards as they extend outwards, so that their upper border is concave and the lower convex; their anterior surface looks upwards and is smooth, while their posterior is inclined downwards and is rough and uneven. Their strength is for the purpose of giving strong attachment to the lumbo-pelvic ligaments. They are on a lower level than the middle of the crest of the ilium, and the ilio-lumbar ligaments extend outwards and upwards from them to the ilium, bounding the false pelvis posteriorly between these bony points. In the transverse processes of this vertebra we have a return to the cervical form where each process arises by two roots, one from the side of the body, and the other from the junction of the pedicle and lamina. In the case of the fifth lumbar, however, the vertebral foramen is represented only by a slight fossa, pierced by small holes for bloodvessels, and the extremity is tubercular and massive, not bifid. At the same time we see here the commencement, in a small way, of that increase of bony matter in the transverse processes which leads to the formation of the lateral masses of the sacrum.

The spinous process is shorter and shallower than those above; the *laminæ* are much more expanded—*i.e.*, wider from the middle line outwards—but much shallower than the laminæ of the rest of the lumbar vertebræ.

THE SACRUM.—*The base* of the sacrum measures from four to four and three-quarter inches from side to side, and is wider in the female than in the male; the variations in the width of different bones do not correspond with those of other dimensions, so that bones which in other respects are unequal may be of the same width. In the centre of the base is an oval-shaped flat facet, which is united by means of the intervertebral fibro-cartilage with the fifth lumbar vertebra. Immediately on either side of this facet the base is constricted from before backwards, but it bulges again near the lateral border where the measurement from front to back varies from two to two and a half inches. Thus on each side of the central facet there is a large non-articular, slightly concave and fan-shaped surface. The articular facet of the base would be oval in shape, if its posterior border were not nearly straight. It measures about two inches from side to side, and one inch from before backwards. It is very slightly cupped in the centre, where the osseous structure looks spongy and porous; but at the circumference there is a margin of from one-eighth to one-quarter of an inch wide, composed of dense and compact bone. The margin of the facet is lipped and projecting, so as to increase the surface to which the intervertebral substance is attached, and consequently the area of support for the superimposed column.

In the separated sacrum the base appears to be horizontal, but in the articulated skeleton, owing to the oblique position of the sacrum and the inclination of the pelvis, the base is directed forwards as well as upwards, and assists in forming the sacro-lumbar or sacro-vertebral angle.

Running outwards and backwards from the margin of the oval facet to the rounded prominence at the posterior and outer angle of the base is an oblique ridge. Also extending outwards from the postero-lateral margin of the facet to the articulating process is another shorter and less marked ridge. Between these ridges and the lateral margin of the facet is a small triangular fossa or depression. From the apex or outer extremity of this depression a sulcus or groove passes, and thus separates the articular process from the rounded prominence. Numerous foramina for bloodvessels perforate the floor of this fossa, and overhanging it is the root of the transverse process of the fifth lumbar vertebra; along the groove passes the posterior primary branch of the fifth lumbar nerve. These ridges and the groove are the representatives of the anterior root of the transverse processes of the pedicle, and of the intervertebral groove, which is seen on the upper surface of each process in the cervical vertebræ. In front of the anterior ridge the bone is depressed, being concave from side to side, and bevelled downwards in front. Limiting the fan-shaped portion of the base externally is the rounded superior border of the lateral mass of the sacrum, the posterior angle of which forms the thick and projecting nodule before referred to. This osseous nodule or prominence, as well as a portion of the superior border immediately in front of it, overhangs the hollow non-articular surface which lodges the interosseous sacro-iliac ligament. The anterior extremity of the superior border is thin and sharp, and passes by a well-rounded curve into the anterior border of the latter mass of the sacrum.

The superior articulating processes of the sacrum are situated behind the fan-shaped portions of the base, one on each side of the middle line. Each is separated from the facet for the intervertebral substance by a deeply grooved and narrow mass of bone which represents the pedicle of the first sacral vertebra. They are situated wide apart, are almost vertical in position, with their articular facets directed backwards and a little inwards, and they project above the level of the base of the sacrum. The facets are concave from side to side, irregularly circular in outline, with a diameter of from half to three-quarters of an inch, and receive the inferior articular processes of the fifth lumbar vertebra. On their non-articular surface is sometimes to be seen a bony prominence corresponding to the mammillary process of the lumbar and lower dorsal vertebræ. The amalgamated contiguous articulating processes of the succeeding sacral vertebræ are represented by tubercles situated just to the inner side of the posterior sacral foramina. By looking into the sacral portion of the spinal canal these tubercles are seen to be supported by strong pedicles which completely separate the anterior and posterior sacral foramina for one pair of nerves from those for the pair above. It will be also seen that both the anterior and posterior primary branches of these nerves must pass above the pedicle in front of the superior articulating process of the succeeding vertebra before they can escape through their respective foramina. In this respect they exactly resemble all the other spinal nerves.

The Superior Laminæ and the Spinous Process.—Sloping downwards very considerably from the lower border of the articulating process and from the thick pedicle is the broad, flat lamina which generally though not invariably meets its fellow of the opposite side to form a rudimentary spinous process. These laminæ are so much sloped downwards and backwards that a large space leading into the spinal canal is left between the last lumbar vertebra and the first sacral. The spinous process is often fused with the corresponding processes of the second and third segments of the sacrum so as to form the sacral crest. In the lower segments of the sacrum the laminæ and spines are deficient, and the spinal canal is completed behind by ligaments only.

The lateral mass of the sacrum is formed by the amalgamation of the transverse processes of the sacral vertebræ, those of the upper three bones being much exaggerated in size. On the front aspect of the bone are seen five horizontal ridges homologous with the anterior roots of the transverse processes of the cervical vertebræ. These ridges extend outwards from the bodies of the sacral segments and are merged into the lateral mass on each side, and like the anterior roots of the cervical transverse processes they are on nearly the same plane as the front surface of the bodies from which they spring.

In the first sacral vertebra this anterior portion of the transverse process is a broad, rounded, thick mass, the upper surface of which forms an important part of the base of the sacrum, and over it passes the anterior primary branch of the fifth lumbar nerve and below it the anterior primary branch of the first sacral nerve. In each succeeding vertebra the anterior portion of the process assists in forming the boundary of two anterior sacral foramina, and over each passes the anterior primary branch of a sacral nerve. That of the fifth vertebra is thin and short, and passes obliquely outwards and upwards to terminate at what is called the angle of the lateral border of the sacrum. This process forms with the transverse process of the coccyx a deep notch traversed by the anterior primary branch of the fifth sacral nerve.

On the posterior aspect of the sacrum are seen the amalgamated posterior roots of the transverse processes. That of the first segment projects in front of and further from the middle line than the superior articulating process. It is separated from the latter, as previously stated, by a deep sulcus, along which courses the posterior primary branch of the fifth lumbar nerve. Those of the other segments are represented by a row of tubercles situated vertically one above the other on the outer side of the posterior sacral foramina.

By comparing the sacrum with the vertebræ in other parts of the spinal column, the formation of the lateral masses and of the foramina, as well as the course of the anterior and posterior sacral nerves, becomes apparent. If on looking to the cervical region in the articulated skeleton one imagines a mass of bone interposed between the tips of the transverse processes of any two contiguous vertebræ, one sees that two foramina would be formed by each mass. One of these would be seen from the front at the side of the body of each vertebra through which the anterior primary branch of the cervical nerve would pass; and the other would be seen from behind between the superior articulating process and the posterior tip of the transverse process, or rather the portion of the lateral mass formed thereby. Through the latter the posterior primary branch of the same nerve would pass. Each of the primary branches of the cervical nerves would then have reached its foramen by passing over the *pedicle* of the vertebra below it, as is the case in each region of the spine, while a lateral mass on the outer side of the foramina would be formed which would exactly correspond to the condition of parts in the sacrum.

The double root of the transverse processes, together with a large deposit of bone in place of the vertebral foramen (suggestive of the condition which aids in the formation of the sacral lateral mass), is seen in the case of the transverse process of the fifth lumbar vertebra.

THE LIGAMENTS of this union are of two kinds, viz., (1) those connected with the sacro-lumbar articulations, and which may be called therefore the *articular or intimate* ligaments; and (2) those extending between non-articular portions of the bones, and which therefore may be called *additional or accessory ligaments.*

1. The articular ligaments which unite the sacrum, and through it the pelvis, to the fifth lumbar vertebra, are of exactly the same character as those which connect the vertebræ with each other. First, there is the amphiarthrodial joint, formed by the intervertebral substance and the bodies of the fifth lumbar vertebra and first segment of the sacrum, together with the anterior and posterior common and short intervertebral ligaments of the column. Secondly, there are the two arthrodial joints, formed by the contiguous articular processes and the capsular ligaments surrounding them. These joints do not require separate description; it is only necessary to remark that the intervertebral substance between the fifth lumbar

vertebra and the sacrum is much thicker than any other, and is much thicker in front than behind.

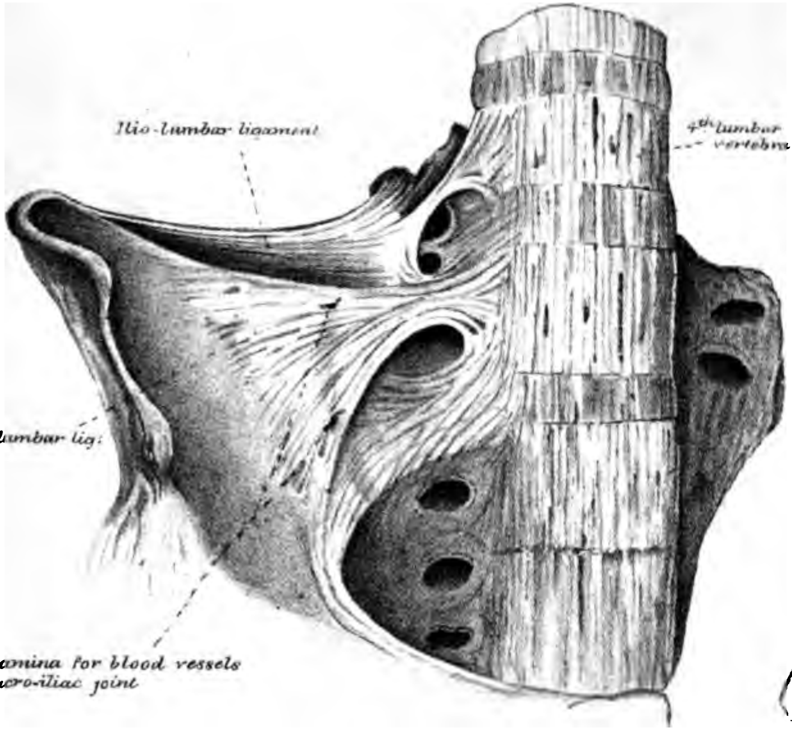
2. The accessory ligaments also correspond to others which are present in the various regions of the vertebral column; only two of them require special notice. They are—First, the ligamenta subflava between the laminæ of the vertebra and the sacrum. Secondly, the interspinous and supra-spinous ligaments between and upon the spine of the vertebra and crest of the sacrum. Thirdly, the sacro-lumbar ligament, a representative of the intertransverse, extends between the transverse process of the vertebra and the non-articular portion of the base of the sacrum. Lastly, the ilio-lumbar ligament extends between the fourth and fifth lumbar vertebræ and the crest of the ilium. It is a representative of the stellate ligament of the dorsal region, for the ossa innominata, homologically considered, constitute the visceral arches of the pelvis as the ribs do of the thorax and abdomen.

The sacro-lumbar ligament is strong, and assists very materially in binding together the pelvis and the spinal column. It attaches the transverse process of the fifth lumbar vertebra to the sacrum and ilium. It is triangular in shape, with its apex internal and above, and its base external and below, at the iliac fossa. At the spine, the ligament is attached to the lower border, from base to tip, of the transverse process, as well as to the pedicle and body of the fifth lumbar vertebra: it is intimately blended with the ilio-lumbar ligaments at their origin. Below it has a wide fan-shaped attachment extending from the edge of the ilio-lumbar ligament forwards to the brim of the true pelvis; behind it reaches a little further back than the posterior edge of insertion of the ilio-lumbar ligament to the iliac crest; elsewhere it is blended with the periosteum of the base of the sacrum, with the superior sacro-iliac ligament and with the periosteum of the ilium, into which it gradually fades away along the iliac fossa.

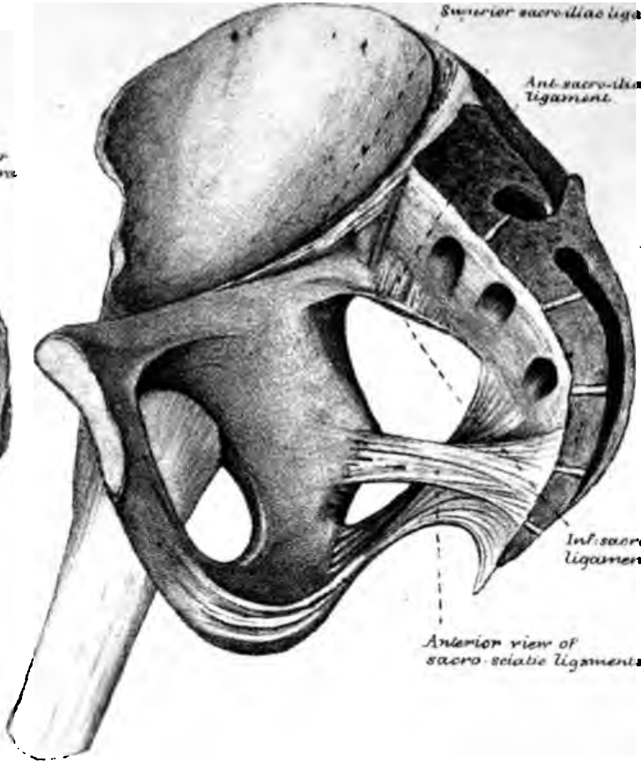
This ligament limits externally the sacro-lumbar intervertebral foramen (*i.e.*, the intervertebral foramen for the last lumbar nerve) by means of a sharp thin border which, descending gradually and in a gentle curve to the base of the sacrum, passes along the brim of the true pelvis and blends with the periosteum, which is there very thick. It is pierced by two large foramina, which transmit arteries into the sacro-iliac joint;

PLATE XI.

1.



2


Superior sacro-iliac ligament
Ant. sacro-iliac ligament
Inf. sacro-iliac ligament
Anterior view of sacro-sciatic ligaments

A. Hensman del. ad. nat.

West Newman & Co. lith.

one of these is a little in front of the ilio-lumbar ligament, the other penetrates the middle of the upper border of the sacro-iliac synchondrosis.

The ilio-lumbar is a strong dense ligament of a triangular shape, having its apex at the spinal column when looked at from behind, and at the ilium when seen from the front. At the ilium, one of its surfaces looks backwards and upwards, the other forwards and downwards towards the iliac fossa; near the spine the surfaces are almost directly forward and backward. Thus the ligament gets somewhat twisted on its own axis as it passes outwards, so as to form more and more a transverse instead of a vertical plane as it approaches its insertion into the crest of the ilium.

At the spine it is connected with the front surface of the transverse process of the fifth lumbar vertebra as far inwards as the body of that bone, and by a strong fasciculus with the posterior surface near the tip of the same process; also with the lower edge and front surface of the transverse process and the pedicle of the fourth lumbar vertebra as far inwards as the body; sometimes, too, a strong slip springs from the inferior articular process of the fourth vertebra.

At the pelvis the ligament is attached to the inner lip of the crest of the ilium for two inches, extending as far forwards as a spot four inches in front of the posterior superior spine of the ilium. The highest fibres at the vertebral column form the anterior edge of the ligament at the pelvis, while those which spring from the back of the transverse process of the fifth lumbar vertebra incline a little backwards as they pass outwards to form the posterior edge of the ligament at the pelvis. Many of the fibres which arise from the front of the transverse process of the fifth lumbar pass almost horizontally outwards to their insertion into the iliac fossa.

When looked at from in front, the ligament appears to have three borders, owing to the twisting of the fibres on the axis of the ligament itself. The lower one is adjacent to the upper edge of the sacro-lumbar ligament and is horizontal in direction; the upper border is oblique and from it the quadratus lumborum arises, and to it the anterior layer of the lumbar fascia is attached; the inner border is crescentic, with its concavity looking inwards towards the median line; it forms the outer boundary of the foramen through which passes the anterior primary branch of the fourth lumbar nerve. The anterior surface of the ligament forms part of the posterior boundary of the cavity of the false pelvis above; and below closely overlies the upper part of the posterior sacro-iliac ligament; the posterior surface looks towards the sacral portion of the spinal groove, the floor of which it helps to form, and it gives origin to the multifidus spinæ muscle.

At the transverse process of the fifth lumbar vertebra the Ilio and sacro-lumbar ligaments are interwoven with one another; some of the fibres of the former decussate with some of those of the latter, and spread downwards upon the side of the body of that vertebra; other fibres of the ilio-lumbar radiate upwards beyond the body of the fifth vertebra, upon the fourth intervertebral substance.

The portion of the ilio-lumbar which arises from the fourth transverse process is inseparably connected with the intertransverse ligament, between the fourth and fifth lumbar vertebræ.

ARTERIES.—There is a very free blood supply on all sides to the structures forming the sacro-vertebral union.

To the amphiarthrodial joint, the lateral sacral, ilio-lumbar, and last lumbar give off twigs which pass between the fibres of the ligaments to enter directly into the bodies of the bones and reach the intervertebral substance; on the posterior aspect, branches pass beneath the posterior common ligament from the arteries of the spinal canal.

The arthrodial joints formed by the articulating processes are supplied by vessels entering the spinal canal through the intervertebral foramina, and by the bloodvessels of the muscles which arise from the articular processes and laminæ.

NERVES.—The nervous supply to these joints is derived from the sympathetic, and from twigs of the fourth and fifth lumbar nerves.

MUSCLES.—The muscles which arise from, or which are in relation with, the structures belonging to the lumbo-pelvic union, are the following:—

Psoas.—This muscle arises from the lumbar vertebræ, including the fifth, and the intervertebral substance between it and the sacrum, as well as from the ilio-lumbar ligament.

Transversalis.—The anterior layer of the posterior aponeurosis of this muscle, which separates the quadratus from the psoas, is connected with the transverse process of the fifth lumbar vertebra and with the ilio-lumbar ligament.

Quadratus lumborum, which arises from the ilio-lumbar ligament, and from the transverse process of each of the lowest three lumbar vertebræ.

Multifidus spinæ, which arises from sacrum, ilium, sacro-iliac, and ilio-lumbar ligaments, as well as from the mammillary process of the fifth lumbar vertebra.

Erector spinæ, especially the longissimus dorsi portion of it. This latter arises by tendons from the accessory processes, and by fleshy slips from the whole length of the transverse processes of the lumbar vertebræ, as well as from the sacrum and lumbar aponeurosis.

Latissimus dorsi, which through the medium of the posterior layer of the lumbar aponeurosis is attached to the spines of both sacrum and fifth lumbar vertebra.

MOVEMENTS.—The angle formed by the sacrum with the spinal column is called the *sacro-vertebral angle.* The pelvic inclination does not, as has been supposed by some, depend entirely on this angle, but in great part upon the obliquity of the innominate bones to the sacrum, so that in *males,* in whom the average pelvic obliquity is a little greater, the average sacro-vertebral angle is considerably less than in *females.*

The sacro-vertebral angle averages 117° in the male, 130° in the female, while the pelvi-vertebral angle—*i.e.,* pelvic inclination—averages 155° in the male, 150° in the female.

The smaller sacro-vertebral angle in the male shows that there is a greater and more sudden change of direction in the sacro-vertebral union than in the female. A part of this change of direction is attributable to the greater thickness in the forepart of the intervertebral substance between the last lumbar vertebra and the sacrum. In both females and males this substance is thicker than any of the others, and thus a greater amount of movement is permitted between those bones than between any two of the lumbar or dorsal vertebræ. The central soft portion of the intervertebral substance is the centre of movements; it is, in fact, the ball upon which those bones revolve, and upon the thickness and amount of this substance the extent though not the direction of those movements depends. So far as this centre of movement is concerned, the motion may take place in any direction. The movements resemble, but are somewhat less limited than, those which occur between any two of the lumbar vertebra. As the diameter of the contiguous bones is less in an antero-posterior than in a transverse direction, the backward and forward movements are freer than the lateral. These backward and forward movements take place each time the sitting is exchanged for the standing position, and *vice versâ*. In rising from the sitting position the back is extended upon the pelvis at the sacro-lumbar union, and the pelvic inclination is also no doubt somewhat increased at the sacro-iliac joints by the action of the erector spinæ muscles. In sitting down the reverse movement takes place—*i.e.*, there is a forward movement at the sacro-lumbar joint. The lateral movement—*i.e.*, flexion from side to side—is also more free between the sacrum and fifth lumbar vertebra than between the lumbar or dorsal vertebræ.

The articular processes provide for the gliding up and down of these contiguous surfaces of the two bones in the extension, flexion, and lateral movements which are permitted upon the intervertebral substance. Further, they allow also of some amount of horizontal movement necessary to the rotation of the pelvis on the spinal column, or of the spinal column on the pelvis. If the inferior articulating processes of the last lumbar vertebra be examined critically, they will be seen to differ considerably from the inferior processes of the rest of the lumbar vertebræ, and to resemble somewhat in direction the corresponding processes of the cervical vertebræ; while the superior articulating processes of the sacrum differ to a similar degree from the superior processes of the lumbar vertebræ. This difference provides for the freer rotation which is possible at the lumbo-pelvic than at the interlumbar joints.

CHAPTER VII.

LIGAMENTS AND JOINTS OF THE PELVIS.

By the term "pelvis" is meant the portion of the skeleton formed by the sacrum, coccyx, and ossa innominata. The space enclosed by these bones is called the "cavity of the pelvis."

The relations of the pelvis to the vertebral column and to the lower limbs should be carefully studied, because it is through the pelvis that the weight of the trunk is transmitted to the extremities, and because it is at the femoro-pelvic joints, *i.e.*, the hip-joints, that the chief movements of the trunk occur.

The sacrum, which is situated at the back of the cavity, and which very largely enters into the formation of the pelvis, is sometimes described as a part of the vertebral column. Like the coccyx, it is an imperfect continuation of the spine, at the lower extremity of which it is placed. It may indeed be regarded as the base of the spinal column of which the head is the capital. Along the bone there runs a canal, complete above, though imperfect below, for the lodgment and protection of the cauda equina. The anterior and posterior sacral foramina are in communication with this canal, and out of them pass the anterior and posterior primary branches respectively of the sacral spinal nerves. Also through the first three segments of the sacrum, as through the vertebræ of the lumbar and other regions of the column, the superincumbent weight of the body is transmitted. Thus in function, as well as in homology of parts and structure, the sacrum is fairly considered a part of the column.

Again, the occipital bone, in so far as it is traversed by the medulla oblongata and transmits the weight of the parts above to those below it, may be looked upon as a modified vertebra, just as the sacrum is regarded as an amalgamation of several modified vertebræ. On the other hand, as the three upper segments of the sacrum transmit the weight of the body, not, as do the vertebræ above them, to the segments below, but to the ossa innominata at their sides; and as they have a very firm connexion with the innominate bones, the whole sacrum may be considered as entering as completely into the formation of the pelvis as the occipital bone does into that of the cranium.

For the above reasons the sacrum is here described as belonging to the pelvis, and the union between the spinal column and the pelvis as being between the last lumbar vertebra and the sacrum. This union is called the sacro-lumbar, and an account of it has been given in the preceding section under the "ligaments and joints which connect the vertebral column with the pelvis." The sacro-iliac joint is described further on in this chapter.

With reference to the union of the pelvis with the lower extremities, it must be noticed that the hip-joints are the chief means of connexion between the trunk and the thighs. In this respect there is a remarkable difference between the upper and lower limbs. The former being required for a wide range of swift and free, and sometimes forcible movements, are connected with the trunk principally by means of muscles. These muscles are of great size and area, pass from both the anterior and posterior surfaces of the body to the arms and shoulders, and extend over the whole length of the back and neck, between the occipital and temporal bones above and the sacrum and ilium below. The only articular or osseous connexion which the upper limbs have with the trunk is at the sterno-clavicular joint.

The lower limbs, on the contrary, are united with the trunk principally by means of the strong capsular ligaments of the hip-joints, especially their upper and outer portion, and by the deep articular cups into which the heads of the thigh bones are fitted; while, with the exception of the psoas, all the muscles which pass from the trunk to the legs arise from one or more of the pelvic bones. Moreover, the ossa innominata or haunch bones, which are the homologues of the clavicles and scapulæ, enter so largely into the construction of the pelvis, are so firmly fixed to the sacrum and to one another, and so immovable with respect to the lower limbs, that they are generally regarded as part of the trunk, and not as belonging to the extremities. On the other hand, the clavicle and scapulæ form no portion of the trunk, while they move freely with the rest of the upper limbs, and are therefore always considered as segments of them. This difference between the arms and legs with respect to their connexion with the trunk pertains throughout the whole class of mammalia.

In connexion with the pelvis there are no less than nine joints. As originally the sacrum was formed of five segments and the coccyx of four, there were of course four articulations special to the former and three to the latter; as a matter of fact, the segments of the coccyx often remain separate until very late in life; but for a description of the joints of the pelvis it suffices to consider the sacrum and coccyx as two complete and separate bones.

First, we have the articulation of the pelvis proper with the vertebral column, consisting of three distinct "sacro-lumbar" joints. Secondly, the os innominatum articulates with the side of the sacrum at the sacro-iliac symphysis. Thirdly, the sacrum forms with the coccyx the sacro-coccygeal joint. Fourthly, the ossa innominata are joined together at the pubic symphysis. Lastly, the pelvis is supported upon the thighs at the hip-joints. Excluding, however, the sacro-lumbar union and the hip-joints four articulations remain which belong to the *pelvis proper.* These are the two sacro-iliac, the pubic, and the sacro-coccygeal articulations; they all belong to the class of mixed or fibro-cartilaginous joints called "amphiarthrosis." The sacro-iliac synchondrosis and pubic symphysis are frequently described as presenting two separate plates of incrusting cartilage, with a small synovial space between them. This condition I have not myself found to exist as a rule; but where it does, the joint ought to be considered as "arthrodial" instead of "amphiarthrodial."

Besides their connexion at the joints, the sacrum and coccyx are bound to each other and also to each innominate bone, by means of the sacro-sciatic ligaments. As, however, these ligaments are more extensively attached to the sacrum and os innominatum than to the coccyx, the description of them is given with the sacro-iliac synchondrosis.

Before describing the joints of the pelvis proper, in detail, attention will be first directed to *some general features of the pelvis as a whole.* By means of its four joints and additional ligaments, the four bones of the pelvis are bound together with sufficient firmness and strength as to be able to support great weight with steadiness and security; the bones so united form an arch along which the weight is transmitted to the lower limbs; the joints in virtue of their elasticity and the movements they permit, act as springs or buffers to prevent shocks; the pelvis affords a fixed point for the attachment of numerous and powerful muscles, and strong and extensive fasciæ; and provides the sockets whereat the trunk moves with free and varied movements upon the buttresses which support the pelvic arch. Further, its admirable architectural arrangements are designed to adapt our frames for the erect posture; consequently the mechanism of the human pelvis differs considerably from that of other animals, none of which, not even the apes, can with ease or for any length of time maintain the erect position, but support themselves on their fore-legs even when they rest upon their haunches.

But this is not all; the cavity enclosed by the pelvis serves to protect, and in some way to support movable and distensible viscera, and forms a short canal through which the fœtus passes in parturition. There is necessarily a marked difference in character between the inner and the outer surfaces of the pelvis. Internally it is very smooth: the bodies of the sacral vertebræ recede from instead of standing forward in the middle line of the cavity, which they assist in bounding, as do the bodies of the dorsal and lumbar vertebræ; there are no rough inequalities or irregularities of the bony wall like the ridge of the petrous bone and the lesser wings of the sphenoid on the inner surface of the cranium; and the ligaments are much thinner than those on the outer surface, and though they assist in holding the several bones together, are little more than greatly thickened periosteum, extending from one to the other. These ligaments form a smooth covering for the margins of the articular surfaces of the bones, without encroaching at all upon the capacity of the canal. Externally the bones of the pelvis are rough and uneven, and the ligaments thick, fasciculated, and irregular. Everything seems to be subsidiary to strength and to the advantageous attachment of muscles of the spine, of the abdomen, and of the lower limbs. For this latter purpose the arch or ring of the pelvis is expanded into outstanding processes; two of these, viz., the ilia, ascend, and by their outer surfaces and borders give rise to the abdominal and gluteal muscles; two project downwards, viz., the ischial tuberosities, and from them muscles arise which act upon the lower limbs; and one curves downwards and forwards, viz., the coccyx, and gives attachment to part of the sacro-sciatic ligaments. Behind the ossa innominata overhang the posterior and rugged surface of the sacrum, and help to form a deep groove on either side of the middle line. In the recent state this is filled up by strong muscles of the back, so that the upper portion of the sacrum is deeply placed below the surface; the last two segments only are superficial, and the fourth is the most posteriorly projecting portion of the pelvis. The descending processes surround what is called the inferior strait or outlet of the pelvis; the ascending bound the cavity of the false pelvis.

The Mechanism of the Pelvis.—The essential feature of the mechanism of the pelvis is the arches which are formed for the transmission of the weight of the body to the points upon which we stand and sit. In each case the sacrum, which supports the lumbar vertebræ, forms the key-stone of the arch; and the innominate bones as far as the acetabula, the pendentives, or *voussoirs*: in the erect attitude, the piers of the arch are the thigh bones, whilst in the sitting position they are the tuberosities and bodies of the ischia. When we stand upright, the pendentives, *i.e.*, the innominate bones, join the piers, *i.e.*, the heads of the thigh bones, at the strongest and deepest part of the wall of the acetabulum, viz., its upper portion. When we sit, the pendentives join the piers, *i.e.*, the ischia, nearly at the same spot, but a little below the deepest part of the socket.

The position of the tuberosity of the ischium is such, that its narrow anterior and lower extremity is in nearly the same vertical line as the posterior edge of the cotyloid notch of the acetabulum, and its thick and broad posterior and upper extremity is vertically below the thick outer wall of the acetabulum. Thus, while the pendentives of both the standing and the sitting arches extend between the acetabulum and the sacro-iliac joint, and are almost identical, the piers of the sitting arch are on a slightly posterior plane to the piers of the standing arch. The latter may be called the femoro-sacral and the former the ischio-sacral arch. These arches are wider, and consequently weaker, in the female than in the male; the greater interval between the piers in women explains their somewhat waddling gait.

When very considerable strength is requisite in an arch it is continued into a ring, so as to form a counter-arch, or what is called a *tie* is made to connect together the ends of the arch, and thus to prevent them from starting outwards. By these means a portion of the superincumbent weight is conveyed to the centre of the counter-arch, and borne in what is called the sine of the arch. The body and horizontal rami of the pubis form the tie or counter-arch of the femoro-sacral, and the united rami of the pubis and ischium the tie of the ischio-sacral arch. Thus the ties of both arches are united in front at the symphysis pubis, which like the sacrum or key-stone is common to both arches. Through the tie, thus formed, of the ischio-femoral arch, the force which tends to push the extremities of that arch upwards and forwards while we sit is conveyed to the symphysis pubis, and thence back along the horizontal rami of the pubis, so that the weight of the trunk is distributed throughout the whole ring of the pelvis. The tie of the femoro-sacral arch not only strengthens that arch itself but resists, at the symphysis pubis, the upward and inward pressure of the heads of the thigh bones at the acetabula. The symphysis pubis is, in fact, the centre of the counter-arch which the anterior portion of the pelvis forms to both the femoro- and the ischio-sacral arches. This explains how it is that so much strain is made upon the symphysis when any increased weight has to be supported by the pelvis, as in pregnancy; why there is such powerlessness, with inability to stand or sit, in cases in which this joint is weakened or diseased; and why the anterior portion of the pelvis yields under the weight of the body, and becomes deformed in rickets and mollities ossium.

In connexion with the femoro-sacral arch, it should be noticed that though the middle portion of the wing of the ilium is thin enough to transmit light, the anterior portion is very thick, and forms quite a strong rib of bone, ascending from the acetabulum to the crest of the ilium. Along this rib of bone part of the direct vertical pressure of the head of the femur is conveyed to the iliac crest, and thus indirectly to the sacro-iliac ligaments and the sacrum, as well as to Poupart's ligament and the pubic symphysis.

The ring formed by the sacrum, the ilia, and the pubes is called the brim of the pelvis, and the area it encloses is called the inlet or the superior outlet of the pelvis. The portion of the brim which is formed by the ilium and pubis on each side is called the linea ilio-pectinea. This bony ring is not circular but somewhat heart-shaped, with its indentation at the sacrum, the base of which encroaches upon the cavity of the pelvis behind, and constitutes what is called the promontory of the sacrum. The apex of the emblematical heart-shaped outline is at the symphysis pubis. The ring is a well-rounded edge or border which divides the expanded cavity of the false from the more contracted cavity of the true pelvis.

As was stated previously, the pelvis is formed by four bones, and these all assist in bounding the cavity of the true pelvis. Into the wall of the false pelvis the coccyx does not enter at all, nor does the sacrum except the lateral masses of its base which are directed forwards and upwards. In the middle line in the articulated skeleton appears the body of the fifth lumbar vertebra, which with the lumbo-pelvic ligaments fills up the space otherwise left between the crests of the ilia.

It should be also noticed that there is a striking difference in the thickness and strength of different parts of the innominate bones, and that while some portions—such, for instance, as the wings of the ilia and the floor of each acetabulum—are so thin as to transmit light, yet all portions along which weight is borne are very thick and strong. The sacrum rapidly diminishes in thickness from above downwards, and chiefly at the expense of its anterior surface, though its posterior surface suffers as well, especially in the deficiency of spinous processes and prominent laminæ.

The weakest points in the pelvis are at or near the junction of the key-stone with the pendentives, at the centre of the counter-arch, and on each side of the latter. Such, however, is the strength of the uniting ligaments, and so firmly is the sacrum, by its doubly wedged shape, locked in between the ossa innominata, that it is a very rare thing for dislocation to occur, although the bones are sometimes fractured by accidents.

The pelvic arches, besides being rigid curves for supporting weight, are also elastic springs to break shocks, and so to preserve the viscera and nerve centres from concussions. The buffer-like cartilages in the sacro-iliac and pubic articulations; the lateral as well as the antero-posterior curve of the sacrum; the forward direction of the base of the sacral wedge; and the obliquity of the pelvis to the vertical and horizontal planes of the body, are all conducive to the elasticity of the pelvis.

The sacrum, owing to its shape and oblique position, has a tendency to turn round an axis, passing transversely through the sacro-iliac joints in such a manner that forces acting on the sacro-vertebral union would, but for the ligaments of the pelvis, throw the promontory of the sacrum downwards and forwards, and tilt the apex of the sacrum and the coccyx upwards and backwards. This tendency could not have existed had the base of the sacrum not been narrower behind than in front. To counteract this tendency there are two very strong and elastic springs, one acting on the sacro-lumbar, and the other on the sacro-coccygeal curves formed by the ilio-lumbar and posterior sacro-iliac ligaments and by the sacro-sciatic ligaments respectively. The ilio-lumbar ligament, which passes backwards and outwards to the crest of the ilium, holds up the last lumbar vertebra, and with it the base of the sacrum, which is thus prevented from rotating forwards; the sacro-sciatic ligaments passing downwards, forwards, and outwards prevent the apex of the sacrum from tilting backwards and upwards; but though by these provisions any undue amount of movement is checked, a considerable amount of elasticity is provided.

The obliquity of the pelvis is another means for increasing the power of breaking shocks by enabling forces applied from below to become distributed throughout the pelvic ring instead of being conveyed at once to the vertebral column, as they must have been had the pelvis occupied a more vertical position. This obliquity is considerable. A line drawn from the promontory of the sacrum to the upper border of the symphysis pubis forms with a line drawn through the chords of the curves of the spinal column an angle of 150° to 155°, and the same antero-posterior line forms with the horizon an angle of from 55° to 60°.

These which are sometimes spoken of as the angles of inclination of the pelvic brim, are greater in man than in woman, and about the same in the infant of both sexes as in man.

There is in the vertebrate kingdom a great variety in the degree of obliquity of the pelvis to the spinal column; and it may be stated as a pretty general rule, that those animals which have the greatest strength have their pelvis placed nearly vertically, *i.e.*, the openings of the cavity of the pelvis are nearly horizontal, and their thigh bones make nearly a right angle with the pelvis; and that those possessed of great speed have their pelvis almost horizontal, *i.e.*, the apertures of the cavity of the pelvis are nearly perpendicular, and their thigh bones make a much more acute angle with the pelvis. In the apes the thigh bones form an obtuse angle with the pelvis. In man, whose pelvis is stronger in proportion to his size than that of any quadruped, the angle of inclination is such that the transverse vertical plane through the bodies of the axis and last lumbar vertebra passes through the acetabula, and the thigh bones in the erect posture deviate but little from the axis of the vertebral column. The centre of gravity of the *whole body* is in this vertical plane at a spot just above the sacro-lumbar angle, and is exactly over the mid-point of a line between the heads of the femora, *i.e.*, the piers of the femoro-sacral arch. In the erect posture the piers of the ischio-sacral arch, *i.e.*, the ischial tuberosities, are somewhat behind the transverse vertical plane; but in sitting upright, owing to the slight flexion of the pelvis on the spine at the sacro-lumbar union, they are brought within the plane through which the line of gravity falls.

If it be remembered that the coccyx is so situated that its tip is a little higher than the lower border of the symphysis pubis, it will be seen at once that the trunk does not (except when thrown far back) rest on a tripod formed by the ischial tuberosities and the coccyx when we are sitting down, as it was erroneously stated to do by some of the older writers.

So far forwards does the sacro-lumbar union project, and so great is the curve of the sacrum, that a line let fall from the front surface of the third lumbar vertebra strikes the upper surface of the symphysis pubis. The inclination of the pubis is such that it helps by its inner surface, which looks upwards as well as backwards, to support some of the abdominal viscera, and during the latter months of pregnancy the enlarged uterus rests upon it in part.

Bony Wall of Pelvis imperfect.—In connexion with the parturient state, it is a fact of great importance that no portion of the cavity of the true pelvis has a bony wall completely surrounding it. Opposite nearly the whole length of the sacrum and on the same horizontal plane with it, is the front wall of the hypogastric region of the abdomen. Opposite to, and on the same horizontal level as the smooth and sloping but extensive plane of bone forming the floor of the acetabulum, are the sacro-sciatic foramina and ligaments, and the obturator foramina. The latter as well as the lower part of the great sacro-sciatic foramina are also on the same horizontal plane as the bodies of the pubes and the pubic symphysis. Moreover, it is a significant fact that the upper border of the symphysis pubis is in the same horizontal plane as the upper segment of the coccyx, while the lower border is a few lines below the lower extremity of the coccyx. Thus the only portion of the anterior wall of the true pelvic cavity, which is formed by bone, has opposite to it the only really movable bone which enters into the formation of the pelvis, viz., the coccyx, the movement of the different segments of which on one another, and of the first segment upon the sacrum, generally remain free until a late period of life. By this movement, which is a backward one upon a transverse axis, at least an extra inch is gained in the antero-posterior diameter of the outlet; when the head of the fœtus has passed into the sub-pubic arch, it is below the level of the coccyx, and the posterior boundary on the horizontal level of the rami of the pubis and ischium is formed by the soft structures of the perineum. In no horizontal plane therefore does the pelvis form a complete bony and unyielding ring, but everywhere the resisting bony portion has opposite to it one and often two or three soft and yielding arcs in the boundary of the cavity. These points have hardly received the attention they merit in the study of the mechanism of parturition.

The Muscles in connexion with the Pelvis.—It has been already stated that one of the leading functions of the pelvis is to afford a fixed point for the attachment of muscles. The number to which it gives origin is very large and their importance is very great. They may be divided, according to their action upon different parts of the body, into two classes—viz., the muscles of the trunk, and the muscles of the lower limb.

1. The muscles of the trunk may again be divided into those of the spine, those of the abdomen, and those of the perineum.

A. The spinal group consists of the multifidus spinæ, the inter-spinalis attached to the upper part of the sacral crest; according to some anatomists, the extensor coccygis to the lower part of the sacrum and to the coccyx; the erector spinæ; and the latissimus dorsi, which, besides having a considerable attachment to the iliac and sacral crests and the vertebral spines, extends beyond the trunk to the bicipital groove of the humerus.

B. The abdominal group includes the external and internal oblique and the transversalis, the quadratus lumborum, the rectus and pyramidalis, and the psoas parvus when present.

C. The perineal group may be subdivided into two, the genito-urinary and the anal.

(*a.*) The genito-urinary set includes in the male the transversus perinæi, the ischio-cavernosus or erector penis, the deep transversus perinæi, and the constrictor urethræ. In the female the muscles of this group arising from the pelvis are the same as those in the male, except that there is no constrictor urethræ, and the erector clitoridis is a diminutive representative of the erector penis.

(*b.*) The anal group consists of the levator ani, the coccygeus, and the external sphincter ani.

2. The muscles of the lower extremity are enumerated further on, and are classed under five heads—viz., the flexors, extensors, adductors, abductors, and rotators of the thigh.

In addition to the muscles several important *fasciæ* get their firm attachment at the pelvis. They are (1) the lumbar fascia, consisting of three layers, the posterior of which is called the vertebral aponeurosis, and is attached to the sacral spines, to the lower part of the posterior surface of the sacrum, and to the posterior half of the iliac crest; the middle layer is the external or more superficial stratum into which the posterior tendon of the transversalis muscle splits; it separates the erector spinæ from the quadratus lumborum, joins with the posterior layer at the outer border of the former, and with the deep or anterior layer at the exterior edge of the latter muscle, and is fixed to the tips of the transverse processes of the lumbar vertebræ and to the inner lip of the iliac crest between the transversalis and iliacus muscles. The anterior or deepest stratum of the fascia lumborum is the anterior layer of the transversalis tendon; it separates the quadratus from the psoas muscle, and is attached to the iliac crest, to the ilio-lumbar ligament, and to the roots of the transverse processes of the lumbar vertebræ.

(2) The abdominal fasciæ—viz., the fascia transversalis which is connected with the inner lip of the crest of the ilium, with the pectineal line, and with the spine and crest of the pubis; and the fascia iliaca which is attached to the brim of the pelvis, the base of the sacrum, the crest of the ilium, and the ilio-lumbar ligament.

3. The fascia lata of the thigh, which is attached nearly all around the margin of the innominate bone on its outer surface, and separates the muscles going to the leg from those belonging to the trunk.

4. The pelvic fascia is connected with the promontory and anterior surface of the sacrum and with the brim of the true pelvis. It blends with the periosteum, the anterior sacro-iliac ligament, and the iliac fascia. Along the origin of the levator ani it separates into the recto-vesical and obturator fasciæ.

5. The perineal fasciæ are deep and superficial. The superficial covers in the anterior perineal region, and is united behind with the deep fascia; but in front it passes into the superficial fascia of the abdomen. The deep perineal fascia, or triangular ligament, is composed of the anterior and posterior layers, between which pass several important structures, including the membranous portion of the urethra.

The lumbar, iliac, and pelvic fasciæ exercise some influence in holding the sacrum and innominate bones together, and add to the security and strength of the pelvis.

The Movements of the Pelvis.—The pelvis moves upon the spinal column at the sacro-lumbar articulations, *i.e.*, sacro-vertebral union; and upon the thighs at the hip-joints.

The movements which occur at the sacro-lumbar joints have been described at the end of the last chapter. It was there stated that they consist of slight forward and backward as well as of lateral inclination; and also of some amount of rotation upon a vertical axis. The lateral movements of the spinal column upon the sacrum can be appreciated by firmly sitting upon a hard seat and bending the body from side to side; the tuberosities of the ischia thus remaining in the same place, the pelvis as a whole is kept immovable, while the lowest part of the column moves upon the sacrum, and the lower lumbar vertebræ upon one another.

The forward and backward, or flexion and extension movements upon a transverse axis, takes place each time the body passes from a standing into a sitting, or from a sitting into a standing position. The pelvic inclination is increased—*i.e.*, a backward or extension movement of the pelvis on the spine occurs —each time the sitting is converted into the standing posture, and a flexion movement each time the standing is exchanged for a sitting attitude. These movements are similar to, though considerably less free than, the flexion and extension of the head on the spine in looking up or down.

2. The pelvis moves upon both thigh bones at the same time, or upon one at once. The movements upon the heads of both bones at the same moment consist of flexion and extension only. This flexion takes place in a forward direction upon a transverse axis through the heads of the femora. Extension beyond the erect position is prevented by the strong anterior portion of the capsular ligament, by the " vasto-rectal" tendinous band of the capsule, and by the mechanical (not the contractile or vital) influence of the ilio-psoas muscle, all of which are quite tight when the trunk is fully extended. It is an important feature in the construction of the human figure, with regard to its adaptation for the erect position, that when the body is upright further rolling of the trunk backwards is thus checked without the expenditure of muscular force, and in a similar manner forward rotation at the knee-joint—*i.e.*, of the tibia upon the condyles—is prevented, and the erect posture maintained, not by muscular action, but by the restraining influence of the posterior ligament (ligamentum Winslowii), and the crucial ligaments of the knee. The only direction in which the trunk can be moved from the upright position at the hip-joints when both feet are on the ground, is forwards; and the only direction in which the thighs can be moved upon the tibiæ when both feet are on the ground, is backwards. Hence the tendency to fall forwards in epilepsy, or fainting, or intoxication, owing to the failure of the muscles which act to keep the trunk upright upon the thighs; and hence too the tendency to drop backwards on to the buttocks when the control over the muscles about the knee is destroyed.

The movements of the pelvis upon one thigh can take place in almost any direction, as the hip-joint is of the ball and socket kind; these movements are limited by the means which will be described under the head of the *Hip-Joint.* To effect the several movements, as well as for the purpose of securely balancing the trunk in any position upon one femur, muscles surround the hip-joint, and extend from the several bones of the pelvis to some point of the thigh or leg bones.

They may be classed in five groups according to their functions, and according to their situation at the pelvis with reference to a vertical line drawn through the acetabulum.

The *flexors of the trunk* are situated in front, and include the rectus, iliacus, and sartorius. The psoas, also a flexor, though not attached to the pelvis, passes along the brim of the pelvis.

The *extensors* are placed behind, and include the hamstrings and the gluteus maximus. The work required of these muscles is to bring the trunk from the stooping into the erect posture; owing to the great weight of the head and trunk and the length of the column of the back, this is the most severe effort which any of the muscles have to make. Hence we find that the gluteus maximus is not only the most bulky muscle, and the muscle of the strongest fibre in the body, but that it has a very extensive origin. It arises from the sacrum, coccyx, and ilium and great sacro-sciatic, and other ligaments which hold the pelvic bones together, but it is connected also with the lumbar fascia. So too the hamstring muscles arise not only from the tuberosity of the ischium, but are continued, structure with structure, into the great sacro-sciatic ligament.

As this ligament by its upper extremity is attached to the posterior part of the ilium, to the sacrum, to the sacro-coccygeal ligaments, and the coccyx, and is blended with part of the posterior sacro-iliac ligament as well as with the lumbar aponeurosis, the hamstring muscles exert traction upon all these parts, and thus not only get a greater leverage for performing the difficult movement they have to accomplish, but (like that of the gluteus maximus) their force is not confined to any one bone of the pelvis, nor even to the pelvis as a whole, but extends to the spinal column beyond, through the lumbar aponeurosis; and further in their pull upon the pelvis their tendency is to hold together and not to separate the several bones which enter into its formation.

The *abductor group* is placed to the outer side of the hip, and includes the gluteus medius and gluteus minimus, and the tensor vaginæ femoris.

The *adductor group* is situated upon the inner side, and includes the several muscles named adductors, together with the gracilis and pectineus. They extend from the anterior extremity of the ischial tuberosity to the superior ramus and to the body of the pubis.

The muscles forming the external *rotator group* are variously situated at the pelvis with regard to a vertical line through the acetabulum, but they all pass to the femur over the lower and posterior part of the hip-joint.

This group consists of the pyriformis, the obturator externus and internus, the gemelli, and quadratus femoris; a set of muscles which, collectively, arise from the inner as well as the outer surface of the pelvis, and from the sacrum as well as from each of the three portions of the innominate bone.

It ought further to be observed that the four groups which affect the angular movements of the pelvis arise from processes of the pelvis which project, on their respective sides, beyond the hip-joint, and in this manner increase the leverage of the muscles; thus the anterior spines of the ilium which give origin to the flexor muscles (sartorius and rectus) overhang the acetabulum in front; the tuberosity of the ischium and the sacrum, coccyx, and back of ilium, which give rise to the extensor muscles, project or overhang behind; the anterior portion of the dorsum ilii from which the great abductor, the gluteus medius, arises, overhangs on the outer side; while all parts of the pelvis from which the adductors proceed project far from the joint on its inner side.

As the leverage afforded by these processes is greater according as they are farther from the axis of motion, it follows that when the balance of the trunk is varied and the difficulty of maintaining a position is thrown more especially upon any one group of muscles, this difficulty is partly met by the increase in the distance between the bony processes from which these muscles arise and the axis of movement, which is in a plane carried vertically through the head of the thigh bone. Thus during flexion the bony parts from which these extensors arise are carried away from this plane; during adduction the bony points from which the abductors, and during abduction those from which the adductors arise, are removed from this axis, and the muscles derive a corresponding advantage in increased leverage. During extension, as has been stated, the flexor muscles are not required to balance the trunk and to prevent it from falling backwards, as the ligaments of the hip-joint serve this purpose; therefore it is that the bony points from which these muscles arise are less strong and less distant from this plane than are the points of origin of the muscles of the other groups.

But the most important and frequent movements of the trunk are not those which take place upon one femur alone, or upon both femora at the same time, but those which occur alternately upon the thigh bones. Such are the movements of walking and running.

In walking, when the right thigh is flexed and carried forward, the body is bent slightly and carried forwards, and the right side of the pelvis is advanced; the trunk by its own weight falls a little upon the right side and is supported by, while it rotates upon, the head of the left thigh bone. Next, the right limb having swung forwards *pendulum-like* as far as the inclination of the body at the time will permit, swings back again a little—like the reverse stroke of the pendulum—so that the right foot may be firmly planted on the ground while the trunk at the same time assumes a nearly vertical position. Then the left thigh is flexed, elevated, and carried forwards, and the trunk is again bent forwards, while the pelvis in turn is supported by and rotates upon the head of the right thigh bone, whereby its left side is advanced.

The movements in running are much the same as those in walking, but while in walking there is always one foot on the ground, in running both feet are for a time off the ground together.

The pendulum-like movement of the legs in man during running and walking is a great economy of muscular energy. The movements are chiefly mechanical; the muscles have only to flex the joints of the lower limbs, but are not required to carry them forwards, nor to straighten them out again previous to planting first one and then the other foot upon the ground.

SACRO-ILIAC SYNCHONDROSIS AND SACRO-SCIATIC LIGAMENTS.

Sacro-iliac Synchondrosis.

Class, **Amphiarthrosis.**

THIS, like the symphysis pubis, is an amphiarthrodial articulation, but it differs from the pubic joint in that, besides having an interosseous or symphysial *cartilage*, and being surrounded by ligaments, the bones are further also held together by a strong interosseous *ligament.*

The bones entering into the joint are the sacrum and ilium.

THE SACRUM.—By its broad irregular *lateral border* the sacrum articulates, with the uneven inner surface of the posterior portion of the expanded wing of the ilium. It is only the portion of this border which corresponds with the amalgamated transverse processes of the three upper sacral vertebræ that is in apposition with the ilium; the rest of the lateral border is free, and gives attachment behind to the great sacro-sciatic ligament, in front to the oblique fibres of the inferior sacro-iliac ligament, and along its free edge to the small sacro-sciatic ligament.

The *articulating portion of the lateral border* diminishes in antero-posterior measurement as it descends, being at the base of the sacrum nearly two inches, and at its lower part but little more than one inch from before backwards. Vertically it measures, in front, between two and two and a half inches, and corresponds pretty accurately with the vertical measurement of the ear-shaped facet of the ilium. Above it is separated from the smooth concave surface of the base by a sharp prominent edge, which extends from the posterior angle of the first transverse process forwards to the front surface of the sacrum.

In front, a prominent, still sharper, and somewhat sinuous edge separates it from the grooves on the front surface or "hollow" of the sacrum, which run outwards from the three upper anterior sacral foramina, as well as from the ridges between the grooves. Posteriorly it is limited by the projecting tubercles of the fused transverse processes, and is separated from the three superior posterior sacral foramina by a ridge, connecting the tubercles with one another. Inferiorly, a rough curved ridge passes from the tubercle of junction of the third and fourth transverse processes to the front edge of the bone, and separates the articulating from the non-articulating portion of the lateral surface.

The articulating portion is further divided by a vertical "*f*"-shaped prominent ridge into two unequal parts; the front part forms an ear-shaped facet for the connecting cartilage, and the hinder part gives attachment to the interosseous ligament. *The facet* projects laterally beyond the rest of the bone, and occupies the anterior and greater portion of the surface, being one inch and a half wide above, and rather more than half an inch wide below. It is not so nearly "ear-shaped" as the corresponding facet on the ilium, being longer with the angle formed by the front and superior borders, less rounded, and more rectangular. This angle projects further forward than any other part of the bone. The facet is concave from above downwards, as well as from side to side; its posterior edge, which is raised and sharply cut, is concave, with the concavity looking backwards and upwards; the anterior edge is convex and sharp, and separates the lateral surface from the "hollow" of the sacrum.

The rough uneven surface, behind the facet, for the interosseous ligament, is of the form of an italic *f*, curving backwards above and forwards below. It is like a rough excavation in the side of the bone, with a broad ridge crossing it (like the cross line of the "*f*") about the middle; this ridge which is formed by the united transverse processes of the first and second vertebræ, gives strong attachment to the interosseous ligament, and separates a deep recess in the lateral mass of the first from another in the lateral mass of the second, and sometimes of the third sacral vertebræ. Into the upper of these two recesses or depressions is received a rough process of the ilium, whereby the two bones are locked into one another, while ligamentous fibres further unite these parts of them together; the lower recess does not receive any corresponding process of ilium, but gives attachment to some very strong fibres of the interosseous ligament, between which a quantity of fat and some of the articular vessels and a nerve are lodged. When united with the ilium, the ridge is on the same level as the posterior superior spine of the ilium; sometimes the lower recess is subdivided into two by a second ridge, formed by the united transverse processes of the second and third vertebræ.

THE ILIUM.—On the posterior part of the inner surface of the wing of the ilium is a very irregular rough surface, the anterior four-fifths of which articulate with the sacrum, while the posterior superior fifth projects backwards and inwards over the posterior surface of the upper part of the sacrum, and assists very considerably in deepening the sacral groove for the erector spinæ muscles. This rough plane is irregularly quadrilateral; its *posterior* border is formed by about three inches of the crest of the ilium; its *anterior*, by a prominent raised lip two inches long, and situated at a distance varying from three-fourths to one-fourth of an inch above and behind the border of the great sacro-sciatic notch; its *superior* border is also a raised lip, about three inches long, extending forwards from the crest of the ilium in a line with the ilio-pectineal ridge, it separates the articular facet from the iliac fossa; *inferiorly*, the border is not more than an inch and a half, and corresponds with the posterior superior and posterior inferior spines of the ilium, and the notch between them.

Extending the whole length of the anterior and along nearly the front half of the superior borders, is *an uneven ear-shaped facet*, half an inch wide at its narrowest part, and somewhat wider above, where the anterior and superior borders of the articular surface form a well-rounded angle with the convexity forwards. This facet, like the corresponding one on the sacrum, gives attachment to the connecting cartilage. Behind it the bone is undulating enough for the attachment of the strong interosseous ligament, and about half-way between the upper and lower borders there is generally a large rough prominence, which fits into the rough superior depression or recess of the sacrum, above the transverse process of the united first and second sacral vertebræ. Immediately behind the lower end of the ear-shaped facet, and curving upwards from the notch between the posterior spines of the ilium, is a well-marked groove, sometimes overhung by a bony plate, for the lodgment and protection of the articular branch of the superior gluteal nerve and gluteal artery. Along the inner side of the crest of the ilium the bone is less uneven, and here affords attachment to the posterior sacro-iliac and the ilio-lumbar ligaments, and gives origin to the erector spinæ and quadratus lumborum muscles.

The articular rough portion forms with the smooth iliac fossa of the ilium an angle of 140°, for while the part of the bone forming the fossa for the iliacus muscle curves inwards behind, the rest of the bone inclines backwards and curves downwards in order to overhang the sacrum. By this means the sacrum is received upon a surface of the ilium much wider than the lateral border of the sacrum itself; and while it is overhung by the ilium behind, it is somewhat underhung by it below. Moreover, the weight of the trunk transmitted through the base of the sacrum, and especially along the ridges which extend from the articulating centrum for the fifth lumbar vertebra to the rounded angle of the ear-shaped facet, is thus communicated directly to the strongest part of the ilium—viz., along the brim of the true pelvis. This brim forms an arch of which the sacrum is the key-stone, and which, descending from the lumbar portion of the spine at an angle of 150°, transmits the whole weight of the trunk to the heads of the femora in the standing posture, and along the ischial arches, to the tuberosities of the ischium in the sitting attitude.

The outer surface or reverse side of the articular portion of the ilium forms a portion of the gluteal fossa or dorsum ilii, from which the gluteus medius arises. It is also marked by an oblique rough ridge running downwards and backwards to the back of the great sacro-sciatic notch, and giving origin, like the bone behind it, to the gluteus maximus muscle.

THE LIGAMENTS.—Ligaments surround the articulation on every side, and cover in the symphysial cartilage. In addition, numerous scattered but strong bands pass between the apposed surfaces of the bones, so as to form a strong interosseous ligament.

The *anterior ligament* consists of well-marked glistening fibres, thickening the periosteum and forming part of a continuous covering over the joint. It passes uninterruptedly into the superior ligament above, and into the inferior ligament below. It blends with the periosteum of the sacrum and ilium, and becomes thinner as it stretches away from the united edges of the bones. It extends from the first three bones of the sacrum to the ilium above the great sacro-iliac foramen.

The *superior ligament* extends across the upper margins of the joint between the base of the sacrum and the iliac fossa. It is far stronger behind, especially beneath the transverse process of the fifth lumbar vertebra, than elsewhere; but it is also well marked along the brim of the pelvis, where it is thickened by some closely packed fibres which pass forwards into the periosteum covering the ilio-pectineal line, and backwards along the oblique ridge of the sacrum to the anterior sacral ligament. This ligament is connected with the strong sacro-lumbar ligament, which spreads outwards and forwards over the joint to reach the iliac fossa and the ilio-pectineal line.

The *posterior ligament* is of very great strength, and consists of a strong expansion of fibres between the back of the sacrum and the posterior two inches of the iliac crest, including the posterior superior spine of the ilium. In addition to, and strengthening the back of this fibrous expansion, at its upper part, there are two or three strong rounded bundles of ligamentous fibres, which extend more or less transversely from the inner surface of the iliac crest (1) to the articular process of the first sacral vertebra, and (2) to the bone between it and the first posterior sacral foramen. Another strong band passes from the ilium to the articular tubercle of the second sacral vertebra, and forms a ridge over the second sacral foramen, under which the second posterior sacral nerve passes. An oblique band often connects this last fasciculus with the articular process of the first sacral vertebra.

Over the lower part of the back of the joint fibres run obliquely downwards and inwards from the inner surface of the hindermost inch of the iliac crest (where they are attached under cover of some of the transverse fibres) to the side of the sacrum, external to the second and third posterior sacral foramina. To the edge of this ligament is attached the lumbar fascia covering the erector spinæ muscle.

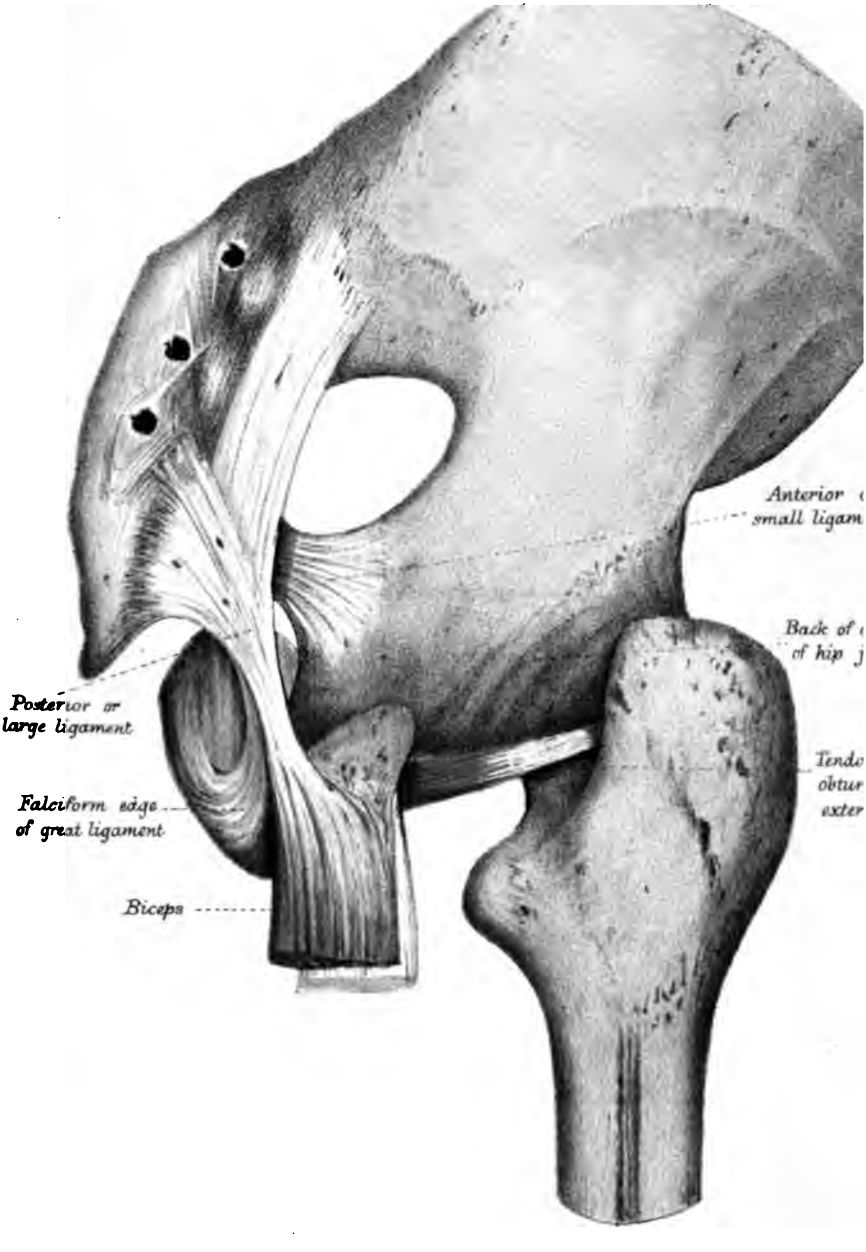
The *inferior ligament* is covered behind by the upper end of the great sacro-sciatic ligament. It consists of some strong fibres which extend upwards from the lateral border of the sacrum below the articular facet, to the posterior iliac spines, while some are attached on the deep surface of the ilium above the inter-spinous notch and join the inter-articular ligament. Some of the anterior fibres of this ligament are very distinct, and take a very oblique course upwards and outwards beneath the lower fibres of the anterior ligament.

The *inter-articular or interosseous ligament* is the strongest of all, except perhaps the posterior sacro-iliac. It consists of fibres of different lengths passing in various directions between the rough surfaces of the two bones. These fibres are attached alike to the depressions and to the intervening ridge of the sacrum on the one side, and to the corresponding portions of the ilium on the other. Immediately above the inter-spinous notch of the ilium the fibres of this ligament are very of the ilium, on the spinous processes of the vertebræ, and on the sacrum, as well as upon the tuber ischii. The amount of leverage which these processes afford is greater than that of the tuberosities of the ischium, in proportion as they are farther away from the axis of rotation of the pelvis—viz., a line drawn through the head of the femur and acetabulum on each side. Thus these muscles get a much more advantageous purchase on the pelvis, and their power in extending the trunk on the thighs is considerably greater than if they had been limited in their attachment, as they are stated to be, to the tuberosity of the ischium. This fact, which seems hitherto to have been overlooked, gives great importance to the ligament, and affords a much more satisfactory explanation of its size and wide connexions than that usually given—viz., that it assists in closing the pelvis. It is not requisite for the latter purpose, as the muscles of the outlet are sufficient for this, while the viscera of the pelvis are supported by their own immediate connexions; and, as a matter of common experience, when these become relaxed, the rectum and uterus descend and become prolapsed, in spite of the ligaments; whilst the whole tendency of the bladder during distension is to rise out of, and not to descend in, the pelvic cavity.

The Small Sacro-sciatic Ligament.—The small or anterior ligament is triangular and thin, with its base at the sacrum and coccyx, and its apex at the spine of the ischium. Its fibres decussate in the same manner as those of the large ligament, so that the anterior and lower fibres pass upwards to the highest point of the ischial spine. It is situated in front of the central part of the great ligament as it passes transversely outwards and forwards, and is closely connected with it near the sacral attachment. It springs from the lateral border of the sacrum and coccyx, from the front of the sacrum both above and below the level of the fourth sacral foramen, and from the coccyx nearly as low down as its apex. At the ischium it is attached to the front surface, and the upper and lower borders of the ischial spine as far outwards as its base. In front it gives support to the coccygeus muscle, which covers it on the pelvic aspect. Behind it is so hidden by the great ligament that only about the outer inch, and a part of its attachment to the coccyx, can be seen from the gluteal aspect. Besides separating the great from the small sciatic foramen, and

PLATE

POSTERIOR VIEW OF THE SACRO-SCIATIC LIGAMENTS SHOWIN THE DIRECT CONTINUITY OF THE HAM STRING TENDONS INT THE GREAT LIGAMENT.



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giving attachment to the coccygeus muscle, it strengthens the thin expansion of the great ligament where this latter is giving origin to the gluteus maximus muscle, and yet is unsupported by bone.

These two ligaments give great additional security to the union of the sacrum with the ilium, and serve to hold the sacrum and coccyx together along their edges.

The ilia are connected and held together, and to the spines of the sacrum, by means of the strong lumbar fascia, which being attached to these bony points assists in retaining the ilia upon the sides of the sacrum.

THE ARTERIES.—All the arteries of the joint are derived from the branches of the internal iliac trunk.

1. The gluteal artery, after giving off its nutrient branch to the ilium and as it is passing through the great sacro-sciatic foramen above the pyriformis muscle, sends a vessel of some size to the lower part of the sacro-iliac synchondrosis, which it enters on the pelvic aspect of the joint. Numerous small branches perforate the iliac attachment of the great sacro-sciatic ligament and reach the margin of the joint.

2. The ilio-lumbar artery, after dividing into iliac and lumbar branches, supplies the upper part of the joint. The lumbar division sends downwards through the lumbo-sacral and superior sacro-sciatic ligaments a large branch. After laying open the joint this articular vessel can be traced a long way down behind the connecting cartilage and amongst the fibres of the interosseous ligament. As it descends it ramifies freely in several directions, supplying the surrounding structures.

Small twigs from the iliac portion of the artery often penetrate the anterior ligament and enter the cartilage.

3. Two or three of the sacral spinal arteries, after they have emerged from the posterior sacral foramina, give off small twigs to the articulation. These penetrate between the bundles of the posterior ligament. A very distinct branch passes from the second posterior sacral artery, runs downwards beneath the oblique portion of the posterior sacro-sciatic ligament, and passes into the joint at the notch between the posterior spines of the ilium. This artery runs amongst the fatty tissue of the joint, and often grooves the ilium behind the lower end of the ear-shaped facet.

Other small branches from the lateral sacral (or the lower of the two when more than one is present) supply the front and lower part of the joint.

THE NERVES.—The nerves are derived from the posterior sacral spinal nerves, from the lumbo-sacral cord, and probably from the lumbar as well as the sacral plexus.

1. The superior gluteal, a branch of the lumbo-sacral cord, as it passes through the great sacro-sciatic notch above the pyriformis with the gluteal artery sends a small nerve with the articular branch of that artery into the lower part of the joint.

2. The part of the sacral plexus formed by the lumbo-sacral cord and first sacral nerve is in close proximity to the joint, and gives off one or two small filaments to the front part of it.

3. The external branches of the first and second posterior sacral nerves, as they pass beneath the multifidus spinæ and under part of the posterior ligament of the joint, send some small twigs to the back part of it.

4. The obturator branch of the lumbar plexus lies over the front of the sacro-iliac synchondrosis, though not quite so near to it as the lumbo-sacral cord. I cannot state from my own knowledge that it supplies the joint, but Mr. Hilton is disposed to think it does, and remarks in his work on *Rest and Pain*, that the nerve "would be likely to suffer from its proximity to it when diseased."

BURSÆ.—There are no bursæ in connexion with the sacro-iliac synchondrosis, as there is no pressure from without exerted upon it, and no tendons play about it.

THE MUSCLES.—There are several large and important muscles in relation with and taking origin near this joint, but none of them produce any movement between the two bones. It will be noticed that each of the muscles arises from both bones, so that during their action they are not exercising any strain upon the ligaments of the articulation by pulling the bones apart, as might be the case if each muscle had been connected with only one bone.

1. Through the medium of the lumbar aponeurosis, the latissimus dorsi is attached to the sacral spines and posterior part of the iliac crest.

2. The erector spinæ arises by muscular fibres from the posterior fifth of the iliac crest, and by tendinous fibres from the hinder part of the ilium and from the lower part of the sacrum

and sacral spines. It is inseparably united with the lumbar aponeurosis.

3. The multifidus spinæ arises from the groove at the back of the sacrum as low as the fourth sacral vertebra, from the inner side of the posterior extremity of the iliac crest, and from the posterior sacro-iliac ligament.

4. The iliacus arises from the base of the sacrum and the iliac fossa of the innominate, as well as from the ligaments over the upper part of the sacro-iliac synchondrosis. The psoas magnus passes over the front and inner side of the joint, but is not attached to either the sacrum or ilium.

5. The pyriformis passes over the front of the articulation, and by its origin is connected with both bones, as well as with the great sacro-sciatic ligament.

6. The gluteus maximus arises from the vertebral aponeurosis which is attached to the sacrum and ilium; from the posterior angle of the ilium, from the back and lower part of the sacrum, and from the great sciatic ligament. It is thus in relation with the inferior posterior aspect of the joint.

THE MOVEMENTS.—It is quite clear, from the nature of the osseous surfaces, from the wedge-shape of the sacrum, and the manner in which it is locked in between the ossa innominata, as well as from the amphiarthrodial character of the articulation, that there can be no actual movement of one bone upon the other. While the joint serves a useful purpose in breaking shocks, and in preventing concussions of the spinal cord and brain, the interosseous cartilage is too thin and too firmly fixed to the bones to allow even of any appreciable yielding, such as occurs upon the intervertebral discs.

It is certain, however, that in disease of this joint sufficient loosening of the ligaments and swelling of the cartilage take place to permit of slight movement, and that thus is to be explained some of the pain experienced in such cases during sitting and standing; positions whereby the sacrum under these circumstances would tend to force apart the ossa innominata, and rotate to a slight degree upon its own transverse axis. It was for centuries a received opinion that during parturition and pregnancy this joint, as well as the pubic symphysis, becomes loosened, so as to allow of an increase in the diameter of the pelvic cavity, by a partial separation of the bones, or by their movement upon one another. When, as occasionally happens, this is the case, the movement at the sacro-iliac joint must be caused by the abdominal muscles acting either directly by raising the pubis, and thereby rotating the innominate bones on the sacrum; or indirectly, and by the contractile efforts of the uterus, in propelling the head of the fœtus, whereby the ligaments are stretched and the capacity increased by a force thus applied from within the pelvic cavity.

The shape of the sacrum, and the mode in which it articulates with the ossa innominata, render its position a secure and ordinarily an immovable one. Being doubly wedge-shaped, with its broader surfaces at the base and on the front, dislocation by forces acting from above downwards, as well as from before backwards, is amply provided against.

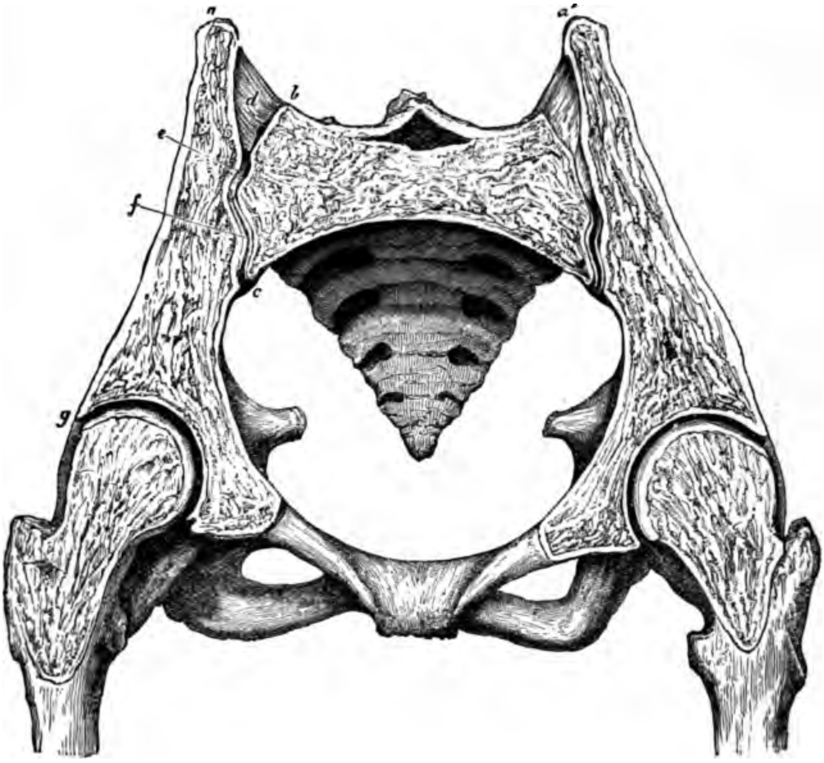
Nor are there wanting provisions against the forward displacement of the sacrum. If sections are made of the sacrum at different levels from above downwards, it will be found that although the majority show the anterior surface of the bone to be wider than the posterior, yet that at a level about opposite to the middle of the auricular facet the posterior surface is generally somewhat broader than the anterior. Again, the sinuous character of the opposed surfaces of the sacrum and ilium is such that eminences of the one are received into fossæ on the other. The posterior extremity of the crest of the ilium on each side projects backwards considerably over the upper part of the sacrum, and by doing so diminishes the effect of any violence before it reaches the back of the sacrum. The direction of the fibres of the posterior sacro-iliac ligament is forwards and inwards from the ilium to the sacrum; the fibres of the sacro-lumbar ligament radiate upon the iliac fossa, and blend with the superior sacro-iliac ligament, while the ilio-lumbar ligament passes outwards to a firm attachment along the iliac crest. All these conditions obviate the forward displacement of the sacrum, by preventing the base of the bone from being carried forwards; while the attachment of the sacro-sciatic ligaments to the ischium on the one side, and to the edges and posterior surface of the sacrum on the other, prevents the tilting backwards and upwards of the lower end of the bone. In this manner rotation forwards is as entirely checked as rotation backwards is by the shape and position of the sacrum.

The downward displacement of the sacrum is impossible, because of the expanded width of the base; whilst the weight of the spine and the connexions of the ligaments, including the ilio- and sacro-lumbar and the great sacro-sciatic, prevent its displacement upwards by any forces which compress the haunches, and which may be powerful enough to break the bones of the pelvic wall, without disturbing the synchondroses.

The anterior and downward displacements of the sacrum are likewise prevented by the interosseous and posterior sacro-sciatic ligaments. Passing as they do between the ilia and the sacrum, they act in the same manner as the chains of a suspension bridge to support the sacrum, the spines of the ilia being the buttresses of the suspension bridge. These ligaments, too, while they resist forces directed downwards and forwards upon the sacrum, at the same time draw the bones more tightly together:

DIAGRAM II.

Diagram of Section of Pelvis through Cotylo-sacral Arch.



a. Posterior spine of ilium. *b c.* Base of sacrum. *d.* Posterior sacro-iliac ligament. *e.* Interosseous ligament. *f.* Ear-shaped connecting cartilage.

the more tightly the greater the disturbing force. This will be understood by referring to the diagram of the section of the pelvis through the cotylo-sacral arch. It will be noticed that the direction of the ligaments is such as to hold upwards and backwards the sacrum between the ilia; and that their section is triangular owing to the ligaments becoming narrower where they fit into the angle between the bones. The suspension bridge construction of the sacro-iliac synchondrosis is admirably adapted to give strength and elasticity to the pelvis.

While the "arch" construction (aided by muscular contraction which assists to hold the bones firmly together, and thus to increase the strength of the arch) affords a strong support for the trunk, the various ligaments of this articulation, together with the ilio-lumbar ligament, break the force of sudden shocks through the resiliency of their "suspension chain" like arrangement.

The wedge-shape of the base of the sacrum, and the wavy section of the joint, are well seen in the above diagram.

The Sacró-coccygeal Articulation.

Class, **Amphiarthrosis.**

This is by no means the unimportant joint which its small size and the meagre descriptions given of it would lead one to suppose. As regards its perfection as an amphiarthrodial joint; the extent and importance of the sacro-sciatic ligaments which assist in binding the bones together; the importance of the muscles which act upon it, and the large size of some of them; and lastly the free nerve and arterial supply to the parts about it, the articulation is well worthy the consideration of the anatomist. From the part it plays during parturition in modifying the shape and diameter of the outlet of the pelvis, it attracts the notice of the accoucheur; while from its being occasionally the seat of real disease and frequently of hysterical pains, the attention of the surgeon has often to be given to it. It especially interests the surgeon to know the nerves and muscles connected with the joint, so that he may by putting the muscles at rest be able to release it from the nerve irritation excited by muscular contractions.

THE SACRUM articulates with the coccyx by means of an oval-shaped and nearly flat surface at its apex, which forms the inferior disc of the body of the last sacral vertebra. The long axis of this surface is transverse and about three-quarters of an inch from side to side. It is bevelled slightly downwards in front. From the sides of this facet the lateral border of the sacrum curves upwards and outwards to the *angle* of the sacrum, forming a notch or concavity looking downwards and outwards, to which the sacro-sciatic ligaments are attached.

In a line with the amalgamated articular processes of the upper sacral vertebræ are *the sacral cornua,* which project downwards somewhat towards the ascending cornua of the coccyx, from which they are separated, however, by an interval varying from one-fourth to half an inch.

Between the sacral cornua is the opening of the spinal canal, which is exposed to a variable extent in different bones according as the laminæ of the fourth and third sacral vertebræ do or do not meet in the middle line. The backs of the exposed sacral bodies are covered in the recent state by the posterior common ligament of the spinal column and give support to the filum terminale, lowest spinal nerves and their ganglia, and the fatty tissue of the canal.

THE COCCYX articulates with the apex of the sacrum by means of a slightly concave facet on the upper aspect of the body of the first coccygeal vertebra. In shape and size this articular facet resembles the corresponding one of the sacrum. It is somewhat bevelled downwards in front, and is rather broader before than behind. It is perhaps altogether a little longer than the surface on the sacrum, which is received upon it. On each side of the body of the first coccygeal vertebra is an outstanding *transverse process,* the upper border of which is on the same level as the articular facet. They increase the transverse measurement of the base of the coccyx by about one-half, so that if the upper facet measures three-quarters of an inch, the bone from tip to tip of its transverse processes measures an inch and a half. Laterally, the transverse processes do not project outwards quite so far as the angles of the sacrum, with which they form the "sacro-coccygeal notch." With the edges of the notch the sacro-sciatic ligaments are connected, and the last sacral nerve escapes from the spinal canal behind them. Ascending, behind, from the point of junction of the transverse processes and the facet, are the *cornua of the coccyx.* They are in the same vertical lines as the cornua of the sacrum, and are from one-sixth to one-fourth of an inch in length. Extending between the cornua along the posterior border of the articular facet is a ridge, which by deepening the margin of the articular surface increases its forward and downward inclination.

The upper half of the posterior surface of the first coccygeal vertebra is smooth and flat (or even slightly concave), and forms the lower extremity of the spinal canal. It also gives attachment to the posterior common ligament of the spinal column, and upon it rests a quantity of the fatty tissue of the spinal canal and the filum terminale, which becomes fixed to the coccyx lower down. Lower down upon the back of the coccyx the continuation of the supra-spinous ligament blends with the posterior common ligament, and together with it is fixed to several segments of the coccyx.

The sloping forwards of the facets of the sacrum and coccyx provides for the forward curve of the terminal part of the spinal column; for although the shape of the sacrum itself secures this in part, the curve of the column at the sacro-coccygeal joint is still more marked in most cases.

The movements of the coccyx on the sacrum are of a hinge-like character, and are provided for by the absence of all bony union behind the centrum of each bone. The cornua of the coccyx on the front aspect of their bases are smooth, and continuous with the articular facet of the coccyx, and are the hinges or pivots upon which the rotation occurs; while the apices of the cornua being free, except for ligamentous connexions, approach in the backward movement of the coccyx the posterior surface of the sacrum.

In advanced life, and after the bodies of the sacrum and coccyx are immovably united, the ligamentous union of the cornua of the two bones is sometimes replaced by osseous tissue, so that the cornua of the sacrum appear to have been originally continuous with those of the coccyx; but it is quite clear that if such had been the case, no movement whatever could at any time have occurred at the sacro-coccygeal joint, and this would be a very serious defect in this articulation in the female. As a rule, the union of the cornua of the sacrum with the coccyx is only ligamentous, even after the bodies of the bones are ossified together.

Sometimes the segments of the coccyx, especially the first two, move on one another long after the sacro-coccygeal joint has been anchylosed; on the other hand, the sacro-coccygeal joint will be sometimes found free after the several segments are immovably united.

Ligaments.—There is an amphiarthrodial joint between the oval-shaped facets of the sacrum and coccyx, as there is between the bodies of the several vertebræ in other parts of the column; but the sacro-coccygeal is by far the most movable of them all.

Besides the ligaments connecting together the bodies of the sacrum and coccyx, others unite them behind, and pass between their cornua as well as over the middle line. In this way the lower end of the spinal canal is covered in, where the laminæ of the sacral and first coccygeal vertebræ being deficient it is left destitute of a bony wall. Strong ligamentous tissue binds the transverse processes of the coccyx to the lateral border of the sacrum.

Intervertebral Substance.—A small intervertebral disc occupies the space between the facets of the sacrum and coccyx. On a transverse section through the joint, it is seen to be about three-fourths of an inch wide from side to side, but somewhat less from before backwards, and to be closely connected with the ligaments which surround the bodies of the two bones. In structure it resembles the rest of the intervertebral substances, but is softer and more jelly-like than they, although the laminæ of the circumferential fibrous portion are well and strongly marked.

The *anterior sacro-coccygeal ligament* is a prolongation of the pearly-white glistening fibrous structure on the front of the sacrum, which is continuous above with the anterior common ligament of the column. It is in fact the lower extremity of the anterior common ligament, which is thicker over this joint than over the central part of either of the bones.

Supra-cornual Ligament.—At the back of the sacrum the vertebral groove of the column becomes very shallow where the bone bends forwards, and ceases to exist about on a level with the lamina of the third vertebra. At this spot the strong aponeurosis of the erector spinæ, which elsewhere blends with the supra-spinous ligament of the column, becomes inseparably woven with it, and is thus prolonged downwards upon the back of the coccyx passing over the lower end of the sacral portion of the spinal canal, which it covers in where the laminæ fail to meet to form a rudimentary spinous process. Some of the fibres of this strong membrane run straight onwards or even curve outwards to their attachment; others, well marked and of a pearly-white appearance, decussate in bundles across the middle line from the stunted lamina of one vertebra to that of the next below, and likewise from the cornu of the sacrum to the cornu of the coccyx on the opposite side. The median non-decussating fibres run over the back of the coccyx to its tip and blend with the posterior common ligament and filum terminale, after roofing in the lower extremity of the spinal canal.

The supra-cornual ligament is composed of a superficial and deep set of fibres, which may be separated without difficulty and without laying open the spinal canal. Some of the deeper-set extend between the cornu of the sacrum and the cornu of the coccyx on the same side, and bridge over the aperture through which the fifth sacral nerve emerges.

Arising from the posterior surface of this ligament or its lateral extension is part of the gluteus maximus. The fascia covering this muscle passes freely over the ligament from side to side. On the deep surface the ligament looks towards the spinal canal, and lower down is attached to the back of the coccyx.

Posterior sacro-coccygeal ligament is a direct continuation of the posterior common ligament of the column. It consists of a well-marked narrow band of closely packed fibres, which passes over the back of the coccyx, and at the lower border of the first segment, or on the back of the second, becomes blended with the supra-spinous ligament and the filum terminale. Resting upon it are the fibrous cord continuous with the spinal marrow and its membranes, the last sacral and coccygeal nerves, the termination of the spinal arterial chain, and the fatty tissue of the spinal canal.

Intertransverse Ligament.—Between the transverse process of the coccyx and the lateral border of the sacrum below its angle, the bones are firmly held together by a quantity of dense fibrous tissue connected with the sacro-sciatic ligaments at their attachment. It scarcely deserves a special name, and would be indistinguishable from the sciatic ligaments except that the great sacro-sciatic is continuous with the supra-cornual ligament, in front of which the fifth sacral nerve escapes while it passes behind the inter-transverse fibres. It is perforated by small branches of the lateral sacral artery, as well as by the coccygeal nerve, on their way to the back of the coccyx.

THE ARTERIES are derived from the lateral sacral, median sacral, and the anterior arterial column of the spinal canal.

Lateral Sacral.—A branch of some size passes back through the ligament above the transverse process of the coccyx, and enters the spinal canal beneath the inter-cornual ligament alongside of the last sacral nerve. It sends a loop upwards on the back of the sacrum to anastomose with the artery which emerges from the last posterior sacral foramen, and one downwards over the transverse process of the coccyx to join with another branch of the lateral sacral trunk. It supplies the structures of the joint. Four or five other branches pierce the coccygeus muscle and the sciatic ligaments to reach the back of the coccyx; one constant branch takes a course along the coccygeal nerve, and enters the lowest extremity of the spinal canal, where it anastomoses like the other spinal arteries and supplies the sacro-coccygeal joint.

The *sacralis-media* sends tiny twigs to the front of the joint, and others from the spinal arterial plexus pierce the joint on its posterior aspect.

THE NERVES.—The anterior as well as the posterior primary branches of both the fifth sacral and coccygeal nerves pass close to, and supply the fibrous structures surrounding this joint.

The posterior branches of the fourth and fifth sacral nerves are partly distributed on the back of the coccyx, and that of the fifth joins in a loop with the posterior primary branch of the coccygeal nerve.

The anterior primary branches of the fifth sacral and of the coccygeal nerve supply the coccygeus muscle, and turn backwards through that muscle and the sciatic ligaments to end in the soft structures on the side and back of the coccyx.

Further, the posterior branches of the second and third sacral nerves descend over the back of the sacrum, forming loops upon the great sciatic ligaments and supplying the gluteus maximus muscle.

These same nerves, which are distributed in the ligaments around the joint, supply the various muscles which act upon the bones.

THE MUSCLES.—The muscles in connexion with the sacro-coccygeal articulation are—

The *gluteus maximus* which, besides its other origins, arises from the side of the coccyx, and last piece of the sacrum on their dorsal aspect, and from the back of the great sacro-sciatic ligament.

The *levator ani* converges to its insertion at the middle line; posterior fibres of this muscle are inserted into the side of the lower end of the coccyx towards the pelvic aspect.

The *coccygeus* diverges to its insertion into the side of the coccyx, and the lower part of the sacrum on their pelvic aspect. It is supported in its whole length by the small sacro-sciatic ligament.

The *external sphincter ani* arises by a small tendon from the tip, and back of the coccyx.

The *hamstring muscles* are attached to the coccyx through the medium of the great sacro-sciatic ligament, with the fibres of which they are directly continuous.

Lastly, a few muscular fibres have been described as sometimes passing from the lower end of the sacrum to the coccyx, both on the front, and posterior aspects. Those in front have been dignified by the name of "curvator coccygis," and those behind by that of "extensor coccygis."

BURSÆ.—There is no bursa usually in connexion with the bones of this joint, or with the muscles at their attachment to them.

THE MOVEMENTS.—The movements of the coccyx on the sacrum, as well as of the pieces of the coccyx on one another, are of a simple backward and forward, hinge-like, character. In the act of defecation the bone is pushed backwards by the escaping fæcal mass, and in parturition by the fœtus: but this backward movement is regulated and controlled by the upward and forward pull of the levator ani and coccygeus. The action of the external sphincter ani tends to pull forwards the coccyx, so as to allow of the tighter contraction of its fibres about the anal orifice.

The muscles which tend to pull the bone backwards are the gluteus maximus, and the hamstring, in such movements as rising from the bent, or sitting postures, and in rapid progression, or in walking with long strides.

Inter-coccygeal Joints.

The several segments of the coccyx are held together by prolongations of the anterior, and posterior common ligaments, which completely cover these bony nodules on their front and posterior aspects. Laterally the sacro-sciatic ligament, being attached to the whole length of the coccyx, serves to connect together its various pieces. Between the first and second pieces of the coccyx there is a very perfect amphiarthrodial joint, with a well-marked intervertebral substance; and in addition, a few ligamentous fibres pass downwards from the cornu of the coccyx on each side, to the posterior surface of the second segment of that bone.

The bloodvessels and nerves of these joints are included under the sacro-coccygeal joint. The same muscles which move the coccyx on the sacrum, move also the pieces of the coccyx on each other.

The Symphysis Pubis.

Class, Amphiarthrosis.

The bones entering into this articulation are the ossa innominata by their pubic portions, where they meet in the middle line of the body. The joint is shorter and broader in the female than in the male, and like the other pelvic articulations is of much importance in obstetrics.

PUBIC BONE.—The *body of the pubis* is flat, of a somewhat triangular shape, and is continuous with the ascending ramus above and the descending ramus below. It extends from the obturator foramen to the articular surface; measures on an average from one and three-quarters to one and a half inches vertically, one and a half inches from side to side, at its upper part, and three-quarters of an inch at its lower end; while at its articular surface it is five-eighths of an inch from before backwards. It is placed obliquely in the body, so that its posterior surface looks somewhat upwards, and its anterior slightly downwards; the joint in consequence is not vertical.

It has two surfaces, namely, anterior and posterior; and three borders, namely, superior, internal, and external.

The *superior border* forms part of the brim of the true pelvis, gives attachment to the rectus abdominis muscle, and is designated in different parts from the middle line outwards the angle, the crest, and the spine of the pubis. The *external border* is a sharp edge forming the upper end of the inner boundary of the obturator foramen.

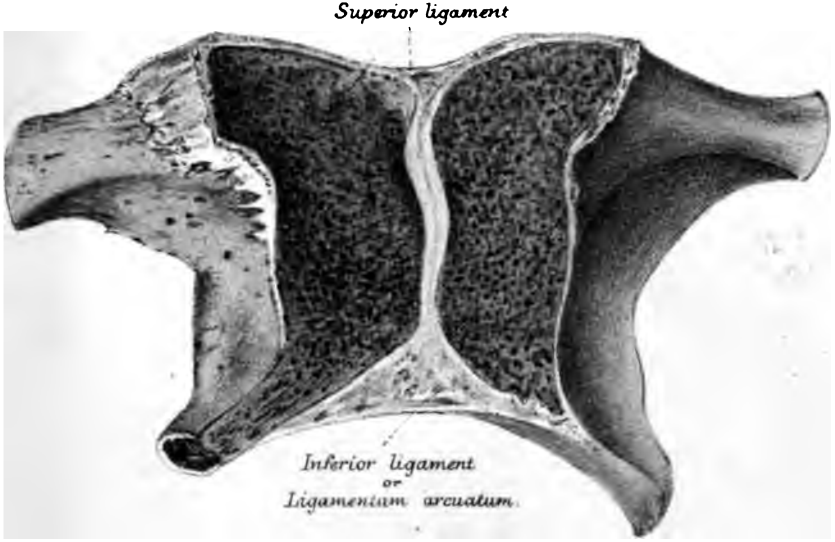
Its Internal or Articular Border.—It is with the inner border that we are especially concerned. It is in the dried bone rough, slightly serrated, and of a nearly oval outline, but narrower at the lower end than above; extending the whole height of the pubic body; and, owing to the eversion of its margins, it is of somewhat greater area than the thickness of the body of the bone elsewhere. It is convex from before backwards; and sometimes convex from above downwards, though occasionally the angle of the pubis overhangs it above. Continuous with it is the inner edge of the descending ramus, which is free and everted so as to form with the corresponding part of the opposite bone the pubic arch. This arch widens as it descends to the ischial tuberosities, and the centre or summit of it is the lower end of the pubic articulation, *i.e.*, the symphysis.

THE LIGAMENTS.—The ligaments completely surround the edges of the articular surfaces of the bones, together with their intervening and connecting cartilage. They are called from their situations—the superior, anterior, inferior, and posterior; and the uniting cartilage is named interosseous.

Interosseous Fibro-cartilage.—The cartilage of the symphysis varies in thickness in different subjects, and is thicker in the female than in the male. It is thicker in front than behind, and projects beyond the edges of the bones, especially the posterior. The several ligaments, especially the lower and posterior, are intimately blended with it at its margins. It varies likewise in its construction—sometimes being uninterruptedly woven throughout, at others having a fissure running through more or less of the antero-posterior as well as of the vertical depth. This fissure is always elongated and narrow; it partially divides the cartilage into two plates, with a minute viscid pulp or a little fluid in the interspace, and usually extends about half the length of the cartilage. It is situated nearer to the posterior than the anterior, and to the upper than the lower border, but does not quite reach to either, and is found in males as well as in females, but not constantly in either sex. I have seen it wanting in females who have died of cancer of the pelvic organs, and whose pelvic bones were soft enough to be transfixed and cut through with a knife. When the fissure is not present, and

TRANSVERSE VERTICAL SECTION THROUGH SYMPHYSIS PUBIS SHOWING FISSURE IN UPPER & BACK PART OF CONNECTING CARTILAGE.

1.



ANTERO POSTERIOR VERTICAL SECTION THROUGH VERTEBRÆ IN DORSAL REGION.

2.

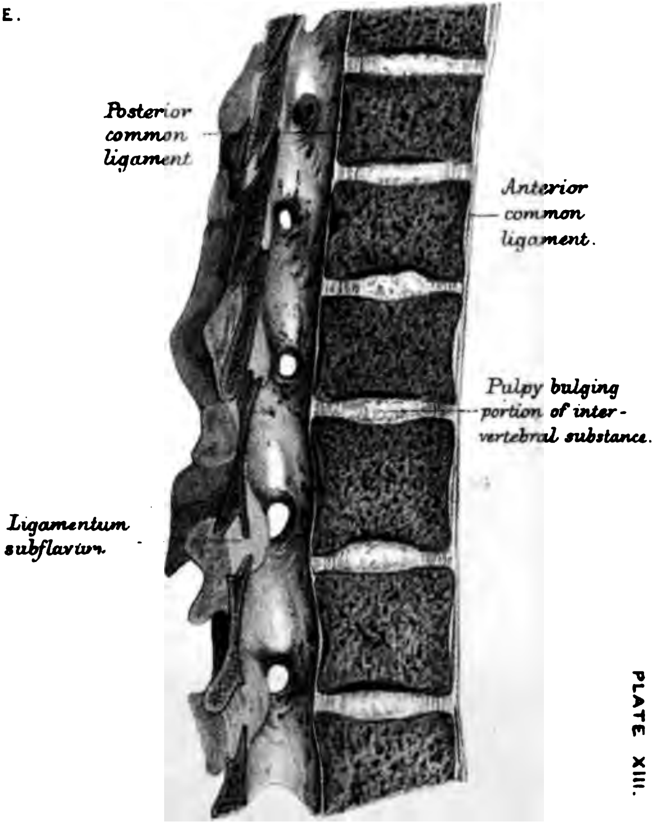

Posterior common ligament
Anterior common ligament.
Pulpy bulging portion of inter-vertebral substance.
Ligamentum subflavum.

PLATE XIII.

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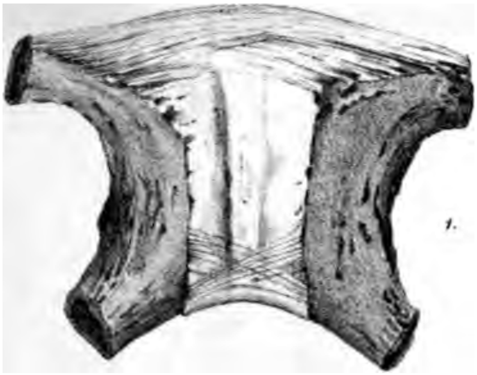
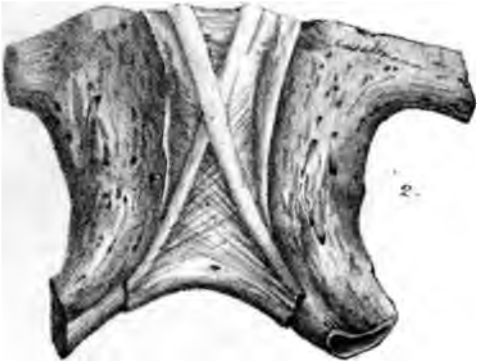
SYMPHYSIS PUBIS

1. Posterior view of pubic symphysis



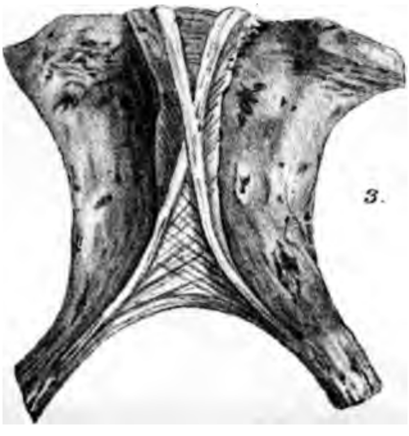
1.

2. Anterior view of pubic symphysis (Female)
Showing decussation of fibres of ligament.



2.

3. Anterior view of pubic symphysis (Male)



3.

[illegible]man del.ad.nat.

West Newman & Co

in the parts beyond it when it is present, coarse white granular-looking fibres pass from side to side through the substance of the cartilage, and firmly weld it together. On forcibly stretching the two bones apart, the cartilage does not always or throughout split into two plates, but is torn from the bone on one or other, or both sides.

This symphysial cartilage is immediately adherent to the osseous surfaces, which are without an independent coating of ordinary articular cartilage.

Superior Ligament.—The superior, or supra-pubic, ligament is a well-marked stratum of yellowish-looking fibres, which extend outwards along the the crest of the pubis on each side, and at the middle line are intimately blended with the interosseous cartilage. It gives origin to the rectus abdominis tendon; in front, it is continuous with the deep transverse fibres of the anterior ligament, and is covered by the tendons of the oblique muscles of the abdomen; behind, it is blended with the strong upper part of the posterior ligament, and with the fibres extending along the ilio-pectineal line.

Posterior Ligament.—The posterior ligament is much slighter than the anterior, and, excepting above and below, consists of little else than thickened periosteum. Near the upper part is a band of strong pearly glistening fibres, which reaches the whole width of the pubic bodies, and is continuous with the fibres which thicken the periosteum along the ilio-pectineal line. Some of these superior fibres decussate obliquely across the middle line, forming gentle arches with their concavity downwards. Below, many of the upper and superficial fibres of the infra-pubic ligament ascend over the back of the joint, interlacing across the middle line with fibres from the opposite side, as high as the middle of the symphysis. Slender fibres faintly decussate between the upper and lower portions of this ligament.

Anterior Ligament.—The anterior ligament is thick and strong, and is closely connected with the fascial covering of the muscles arising from the body of the pubis. In front, it is covered by the interlacing fibres of the pillars of the external abdominal ring, and by the conjoined tendon, and pyramidalis muscle. It consists of several strata of thick decussating fibres of different degrees of obliquity, the superficial being the most oblique and extending the lowest over the joint.

The most superficial descending fibres extend from the upper border of the pubis, cross others from the corresponding part of the opposite bone above the middle of the symphysis, and are attached to the ramus of the opposite pubis. The most superficial ascending fibres, being inseparably connected with the infra-pubic ligament, arch upwards, decussate with other fibres across the middle line, and are lost on the opposite side beneath the descending set. In a deeper stratum the descending fibres arise below the angles, interlace with others from the other side, but do not descend so far as the superficial sets; the deeper ascending fibres decussate, and reach higher than the more superficial ascending sets; but, like them, are inseparable from the inferior ligament.

Some few fibres pass transversely from side to side, more especially above and below the point of decussation of the descending deep set.

Inferior Ligament.—The inferior, or infra-pubic, ligament, called also the *ligamentum arcuatum*, is an arch-like and thick band of closely packed glistening fibres, which fill up the angle between the pubic rami, limit the symphysis below, and form a smooth rounded summit to the pubic arch, which is one of the cardinal obstetric points of the pelvis. On transverse section it is of a yellow colour, like the supra-pubic ligament; it is inseparably connected with the interosseous cartilage, and measures about three-eighths of an inch, vertically, in the middle line. The lower component fibres pass from one side of the pubic arch to the other, below the symphysis, while the other fibres are shorter and end nearer and nearer to the middle line on the opposite side as they lie deeper and deeper.

It has been stated above, that the lower decussating fibres on both front and posterior aspects of the joint are prolonged upwards from the sub-pubic ligament; in fact, this ligament may be said to split superiorly into two thin layers, one of which passes some distance upwards over the front, and the other over the back of the articulation.

Nothing can more firmly brace the pubic bones together than this interlacement of fibres in the anterior and inferior ligaments. Whatever tendency there is for the joint to be dislocated, either by the violent action of the abdominal muscles, or from blows, or compressing forces applied to the pelvis as a whole, or by weights borne or carried upon the crest of the ilium, is successfully resisted by the interosseous cartilage aided by these strata of decussating fibres.

Passing as they do over the front and lower part of the symphysis in every direction, they can withstand considerable force, no matter how applied, and as a practical consequence we hear of fractures of the pelvis and ischium, but never of dislocation at the symphysis.

The necessity of a stronger anterior than posterior ligament arises from the downward and forward drag of the adductor muscles of the thighs, and of the abdominal walls in stout persons; and from the tendency of compressing forces when applied to the sides of the pelvis to burst forwards the bones at this joint, just as in fractures of the ribs from indirect violence, the fractured ends start outwards away from the cavity of the pleura.

THE ARTERIES.—Numerous small vessels ramify upon the posterior surface of this joint.

Blood is supplied to the symphysis pubis from the internal and external iliac as well as from the femoral trunks by means of small arterial twigs which pierce the interosseous cartilage on the anterior and posterior aspects of the joint.

From the *internal iliac trunk.*—(1) The internal pubic artery just before it passes below the sub-pubic ligament gives a branch which pierces the symphysial cartilage low down on the posterior surface.

(2) One or more twigs are sent from the pubic branches of the obturator artery to pierce the posterior ligament, and enter the joint about the middle or a little higher.

From the *external iliac trunk.*—(3) The pubic branch of the deep epigastric artery sends a small vessel to the upper part of the articulation. Mounting over the crest of the pubis it descends through the tendon of origin of the rectus muscle, and penetrates the front of the cartilage.

From the *deep femoral.*—(4) The ascending branch of the internal circumflex sends small twigs through the origin of the gracilis to the front of the joint.

From the *common femoral.*—(5) The superficial external pudic sends small twigs to the upper and front part of the symphysis. They perforate the anterior ligament, but do not always penetrate the cartilage.

BURSÆ.—There are no bursæ in connexion with this joint.

THE MUSCLES.—There are muscles on both the upper and anterior aspects.

(1) Along the upper border of the articulation is the *rectus abdominis*, which arises from the crest and superior ligament of the pubis. Also attached to this border of the symphysis in the middle line is the linea alba, which separates the rectus of one side from that of the other.

Attached to the front of the pubis are the aponeurosis of the external oblique, and the conjoined tendon of the internal oblique and transversalis abdominis muscles.

(2) That portion of the *aponeurosis of the external oblique* which forms the pillars of the abdominal ring passes over the front of the joint in the following way: the inner fibres of the external pillar are continued over the crest of the bone, and beneath the spermatic cord in the male; form what is called the "triangular ligament;" and decussate with the fibres of the opposite side. The inner pillar is attached to the angle of the pubis and to the front of the symphysis, where its fibres interlace with those of the opposite side.

(3) Behind the external oblique is the *conjoined tendon of the internal oblique and transversalis*, which is attached in part to the front of the symphysis.

(4) Behind and above this again, and arising from the anterior and superior ligaments, is the small *pyramidalis*. Immediately on each side of the symphysis, in front, are the *adductor longus* and *gracilis*.

Below and behind no muscles are in connexion with the articulation; but the *levator ani*, which arises in part from the middle of the posterior surface of the body of the pubis, is very near to the symphysis behind.

THE MOVEMENTS.—Being an amphiarthrodial joint there is but little movement, amounting only to a slight yielding of the cartilage. Neither muscular action nor extrinsic forces produce any appreciable movement in the ordinary condition. Occasionally, however, as the result of child-bearing, the joint becomes unnaturally loose, and walking and standing are rendered painful and unsteady, if not actually impossible. In the case of a lady after the birth of her second child, this condition ensued and has persisted several years, in spite of treatment by rest and bandages; and in her it produces such a degree of insecurity, that she requires to use a tight belt around the pelvis to give firmness to the trunk during the action of the muscles of the thigh. It is known that during pregnancy and parturition, the symphysial cartilage becomes softer and more vascular, so as to permit of the temporary enlargement of the pelvis; doubtless for this purpose the joint is very freely supplied with blood. This being the case, it might be supposed that the abdominal muscles, attached as they are to the top and front of the joint, would help to increase the outlet of the pelvis by elevating and somewhat rotating forwards, during their expulsive action, the lower ends of the ossa pubis; that in fact they would produce a slight movement resembling the movement of the ribs during inspiration, which increases the diameter of the chest by their elevation and the rotation outwards of their lower borders.

But it must also be remembered, although the recti may elevate, and the oblique muscles may rotate the pubic bones, that many of the fibres of the latter decussate, and that therefore, when in action, the tendency of these muscles must partly be to draw the bones together. Thus at the very moment they increase the strain on the joint, by forcing down the head of the child, they give it greater strength to bear the strain.

In cases in which the antero-posterior diameter of the pelvis is much contracted, and natural labour impossible, M. Sigault proposed, in 1768, that division of the symphysis pubis should be performed instead of Cæsarian section for the purpose of saving the child and delivering the mother. Experiments, however, prove that in order to gain half an inch in the antero-posterior diameter, the pubic bones must be separated to the extent of two inches. On simple division of the joint, although the bones gape a little, much force is required to widen the gap, and when the separation extends an inch and a half, it has been found that the sacro-iliac ligaments are lacerated, and much damage done to the bladder and its attachments.

For these reasons, although M. Sigault received a medal, pension, and extravagant applause for his invention, the "Sigaultean operation" has been entirely abolished from obstetric practice, at any rate in Great Britain.

CHAPTER VIII.

THE THORAX.

THE *Thorax* is the name given to the parietes of the upper portion of the trunk. These are composed partly of osseous and cartilaginous, and partly of muscular structures. The bones and cartilages consist of the dorsal vertebræ and their intervertebral substances behind, the ribs on either side, and the costal cartilages and the sternum in front. They are so joined with one another as to permit of free mobility in various directions, whereby the cubic capacity of the thoracic cavity can be increased or diminished; while at the same time they are so securely locked together as to afford protection to the organs which they help to surround.

The *cavity of the thorax* is the whole of the space enclosed by the five upper costal arches, and the circumferential portion of the space enclosed by the seven lower arches. But more than the "cavity of the thorax" is walled in by the osseous, cartilaginous, and muscular structures which form "the thorax." The diaphragm forms the floor of the cavity of the thorax; but the muscular fibres of the diaphragm, though they arise from the lower six ribs, and from the xiphoid cartilage, arch upwards to the central tendon of the muscle, which is placed as high as the level of the fifth intercostal space. Thus a considerable part of the viscera of the abdomen is contained within the boundary of the thoracic framework. Indeed, in the mammalian class the space bounded by the thorax may be described as being divided into two parts by the diaphragm. Of these, the upper is the "cavity of the thorax" proper, and contains the heart and lungs, and several important structures on their way to the abdomen—viz., the descending aorta, the œsophagus, and pneumo-gastric nerves; the phrenic nerves on their way to the diaphragm; the ganglionated cord of the sympathetic; the thoracic duct also passes through the thoracic cavity on its way to the root of the neck; and the vena azygos as it ascends to the superior vena cava. The lower division forms a large portion of the cavity of the abdomen, and contains the stomach, liver, spleen, supra-renal capsules, kidneys, part of the intestines, descending aorta and inferior cava.

The bony part of the thorax in the human subject stops short of the pelvis, for the purpose of allowing a moderate range of flexion and rotation of the trunk. To facilitate these movements the lowest two ribs are small, short, and attached only at their vertebral extremity; while the costal arches immediately above slant upwards towards the median line in front, and each is attached to the costal cartilage of the arch next above it.

The Apertures of the Thorax.—The superior is wider from side to side than from before backwards. It is about sixteen inches in circumference, and being the smaller end is called the apex. It is bounded in front by the upper end of the sternum and the inter-clavicular ligament, laterally by the first costal arch of the two sides, and posteriorly by the first dorsal vertebra.

The inferior aperture is about thirty-one inches in circumference, and forms the base of the chest. It is bounded in front by the xiphoid cartilage and the cartilages of the three superior false ribs; laterally by the bodies of those ribs, and the eleventh and twelfth costal arches; posteriorly by the last dorsal vertebra.

In the living subject the thorax looks conical with its base above; this is owing to the breadth of the shoulders, but as soon as the upper extremities are removed the base of the cone is seen to be below and the apex above. Hence the idea that broad shoulders and a broad back indicate great breadth of thorax and great breathing capacity, is a mistake. The diameter of the neck is a better index to the diameter of the true thoracic cavity.

The shape of the thorax, both externally and internally, varies with age, and is affected by disease and occupation. In the fœtal thorax the sternum projects forwards, and the antero-posterior diameter exceeds the transverse; and as the ribs are less curved at their angles, those deep grooves seen from the interior on each side of the spine in adult life are almost wanting. In the decline of life the thorax has a tendency to contract and droop forward. Lateral and angular curvature of the spine; lung diseases, such as emphysema and phthisis; and the pressure of tight-lacing, or of awkward nursing, all cause alterations in the conformity of the thorax. Again, the tailor and the clerk have a different shaped thorax to that of the mountaineer or the sailor.

Externally the thorax varies also with the sex, for in women there is less breadth of shoulders and greater fulness in front, owing to the largeness of the mammæ. Tha internal form of the thorax is the same in males and females, except that in the latter it is *absolutely* smaller.

Throughout the vertebrate kingdom the thorax is constructed upon an uniform plan, although the whole of the bony and cartilaginous structures above enumerated are not invariably present in all the lower orders of this kingdom. Frogs have a sternum, but no ribs; serpents have ribs, but no sternum; tortoises have ribs, vertebræ, and sternum fused together into one rigid and inflexible mass; the crocodile and lizard have perfect ribs, but their sternum is almost entirely cartilaginous. The great characteristic of the thorax of man is the excess of the transverse over the antero-posterior measurement. In all the lower mammalia the vertical, which corresponds to the antero-posterior in man, exceeds the transverse; and though in the quadrumana the transverse equals, and in some cases exceeds the antero-posterior, it never has such a great proportionate breadth as in man.

Another characteristic of man's thorax is the sharp backward curve of the ribs from their heads to their angles, whereby the latter points are brought into nearly the same transverse plane as the spinous processes of the vertebræ. This is a provision for the proper balancing of the body in the erect position, and is a necessity of that position and of the biped mode of progression. It also gives breadth and flatness to the middle portion of the back, and adds to the strength and perfection of the figure. Man is thus too enabled to be at rest upon his back, a position which but for this backward curve of the ribs would be uncomfortable, if not actually impossible, on account of the prominence of the spines of the vertebræ. This backward curve of the ribs, together with the projection forward of the bodies of the dorsal vertebræ, renders the antero-posterior diameter much less in the middle line than at an inch on either side of the median line. The average forward projection of the spine is about two and a half inches, and the average antero-posterior diameter between the bodies of the vertebræ and the sternum is but little more than four inches; even this is much reduced in phthisis, when the vertebral column has the appearance of being wedged forwards towards the sternum.

The curvature of the several ribs varies much; it undergoes a gradual diminution from the first to the last, in which the angle can scarcely be said to exist at all.

In addition to the general curvature in the horizontal direction, the ribs are also curved vertically. This vertical curve too varies in different ribs, but is such as to make it impossible for the rib to lie with both its ends at the same time on a flat surface.

All the ribs incline obliquely downwards from the spine; the upper border of the sternum is on the level of the second dorsal vertebra, being usually not more than two inches from the spine. The intercostal spaces are wider beyond the angle and towards the anterior extremity of the ribs than near the spinal column, but towards the median line in front the spaces become very narrow, owing to the way in which the costal cartilages converge to the sternum or to one another. The several spaces are not of uniform width; the first, second, and third being, as a rule, broader than the succeeding; the tenth and eleventh are generally the widest. There is no uniformity in the corresponding spaces of the two sides of the body.

The joints of the thorax are numerous, and consist of—

24 between the heads of ribs and the bodies of vertebræ. These are called the *costo-central.*

20 between the tubercles of the ribs and the transverse processes of vertebræ—the *costo-transverse.*

14 between costal cartilages and sternum—the *chondro-sternal.*

6 between cartilages—the "*inter-chondral.*"

24 between ribs and their own costal cartilages—the *costo-chondral.*

Besides the above, and the union of the various segments of the sternum with one another, more especially of the manubrium and xiphoid, with the body of that bone, there are the joints between the bodies of the vertebræ.

THE COSTO-VERTEBRAL ARTICULATIONS; OR, THE LIGAMENTS AND JOINTS WHICH CONNECT THE VERTEBRAL COLUMN WITH THE RIBS.

The costo-vertebral joints and ligaments consist of two sets—viz., (*a*) those which connect the head of the rib with the bodies of the vertebræ and the intervertebral substance to form the costo-central articulation; and (*b*) those which connect the neck and tubercle of the rib with the transverse process of the vertebra to form the costo-transverse articulation.

The Costo-central Articulation.

Class, Diarthrosis. *Subdivision*, Ginglymus.

This is a ginglymoid or hinge-joint, having an up-and-down movement upon an obliquely transverse axis, combined with some slight backward and forward motion. It is a very perfect joint, with an inter-articular, an anterior or stellate, and a capsular ligament. In the case of the first, tenth, eleventh, and twelfth ribs, exception must be made to the general description which follows, on the ground that each of those ribs articulates with only one vertebra, and with no intervertebral substance at all, consequently they have no inter-articular ligament, and there is not the same perfect stellate outline to their anterior costo-central ligament.

We must first notice the markings on the bodies of the vertebræ and on the head of the ribs, and then consider the ligaments which bind the bones together.

THE VERTEBRÆ.—There are two half-facets on each side of the dorsal vertebræ, from the second to the eighth inclusive. These are placed one at the upper, the other at the lower border of the body, far back upon its side. Indeed, the upper half-facet, in most instances, is situated as much upon the outer surface of the pedicle, near its upper border, as upon the side and upper border of the body, whilst the lower facet is directed downwards and outwards, and slightly backwards upon a prominent overhanging tubercle of bone, which is continued above into the curved lower edge of the pedicle. The prominence of these overhanging tubercles, upon which the lower half-facets are situated, is most marked in the upper six vertebræ. The lower facets are more uniform in shape and size than the upper, somewhat circular in outline, and never larger than a split pea. The upper facets are sometimes circular like the lower, but are more frequently crescentic in shape, and elongated from before backwards, with their concavity upwards; they are generally rather larger than the lower, and give the idea of having been more worn by friction. This no doubt is actually the case, for as the *upper* facet on each side of each vertebra forms the *lower* half of the articulation for its own rib, it bears most of the direct inward pressure of the rib; whereas the lower facet of the vertebra above resists the upward tendency which is given to the head of the rib by the action of the elevator muscles, and for this purpose it looks downwards and overhangs the rest of the articulation.

In the first dorsal vertebra there is an entire facet near the upper border on each side of the body close to where the pedicle springs. This part of the first dorsal is prolonged upwards on each side as are the cervical vertebræ, so as to give the well-marked transverse concavity to the upper disc of the body. In this way room is provided for the whole of the head of the first rib without encroaching unduly on the side of the body, or approximating the first too nearly to the second rib. As the first rib is almost horizontal and immovable, there is no necessity for any overhanging tubercle at its upper border. The demi-facet at the lower border resembles those of the vertebræ below. In the ninth vertebra there is only half a facet on each side at the upper border which forms part of the socket for the ninth rib. This demi-facet is situated a good way back, and extends partly upon the upper and outer border of the pedicle. At the lower border of this bone there is, as in the vertebra above, an overhanging prominent tubercle; but usually there is no half-facet upon it for the tenth rib.

On the tenth vertebra there is a circular entire facet at the upper border, and an overhanging non-articular tubercle at the lower.

On the eleventh vertebra the single articular facet is a little lower down on the side of the body, extends often upon the outer surface of the pedicle, and has a small overhanging tubercle at its upper border.

There is a slightly marked tubercle at the lower border of the body of this vertebra, which can have, however, no effect in resisting the upward tendency of the twelfth rib, but like a similar one on the lower border of the twelfth vertebra, is only the representative of a part which in the bones above has a definite function.

On the twelfth dorsal vertebra the entire facet for the twelfth rib is still lower down on the side of the body, and is surmounted by a well-marked tubercle between its margin and the upper border of the vertebra.

THE RIBS.—The rib articulates with the vertebræ by its head. The head of the rib consists of a facet on the somewhat enlarged extremity of the bone, the external surface of which is bevelled off to form it. This facet cannot therefore be seen from before, as it nowhere extends upon the inner surface. The vertical diameter of the articular surface equals the depth of the rib; the horizontal diameter is from one-fourth to three-eighths of an inch. The surface is very oblique in direction, being sloped from behind forwards and inwards to the extremity of the inner surface. In all the ribs from the second to the ninth inclusive, the facet is divided into two parts by a nearly transverse ridge; the lower segment is larger than the upper, and though nearly vertical looks slightly downwards: the upper segment looks considerably upwards, and is prolonged a little along the upper edge of the bone. The anterior edge of the facet is V-shaped; the point of the V corresponds to the anterior extremity of the ridge between the two segments of the articular surface which gives attachment to the inter-articular ligament. The posterior, upper, and lower borders of the facet are rough, prominent, and well defined. It is upon the transverse ridge and its ligamentous connexion with the intervertebral substance that the rotation of the rib takes place; and it is to resist the upward pull of the muscles which produce the rotation, that the upper part of the facets is inclined upwards so as to be locked against the overhanging and downward-looking facet on the lower border of the upper of the two vertebræ with which it articulates.

The first rib presents an undivided concavo-convex facet which, though situated more fully on the extremity than in the other ribs, still bevels off the posterior, *i.e.*, external surface, to a slight degree. The articular surface is not larger than the upper segment of the facet of most of the succeeding ribs, and has a prominent and well-defined border separating it from the constricted neck.

The tenth rib has frequently only a single slightly concave facet, which extends nearly the whole vertical depth of the rib; like the rest it is bevelled at the expense of the external surface, and cannot be seen from in front; it is overhung above and below by a rounded prominent margin.

The eleventh is very similar to the tenth; but the tenth occasionally shows a very unequal division of its facets for two vertebræ, the upper one being very small. The facet of the eleventh is always single.

The twelth has a small articular facet which occupies only half the depth of the bone, and extends upwards from the lower border of the rib. It is overhung by a prominent and tuberculous little mass of bone which very effectively prevents its too great elevation. It is formed at the expense of the external surface of the rib.

It will be seen on looking to one of the middle articulations in the recently dissected subject, that the vertebræ and intervening intervertebral substance form for the head of the rib a well-marked concave surface, with a trochlea or pulley-like groove opposite the fibro-cartilage; that, conversely, the head of the rib presents a suitable convexity from above downwards, and that the summit of the convexity, which is the ridge dividing the facet, plays in the deepest part of the trochlea. The same kind of arrangement is seen on the bony surfaces of most of the other ginglymoid joints of the body; it exists in all the central costo-vertebral joints, from the second to the ninth inclusive.

THE LIGAMENTS.—There are three sets of ligaments in this joint—1. The capsular; 2, the inter-articular; 3, the stellate, or anterior costo-central.

The *capsular ligament* consists of short, strong, woolly fibres, which are attached to each of the bones and to the intervertebral substance a little beyond their articular margins. It completely surrounds the joint, and at its upper part reaches a little way around the intervertebral foramen towards the backs of the bodies of the vertebræ, and so into the spinal canal. Here the capsule is covered and strengthened by fibres which at intervals connect the posterior with the anterior common ligament, by curving upwards over the root of the pedicle of the lower of the two vertebræ which bounds the intervertebral foramen through which they pass. In this way the upward strain of the head of the rib during elevation of the thorax is in part resisted. Below, the capsule consists of somewhat longer fibres than elsewhere, which extend downwards to the tubercle upon which is situated the demi-facet for the rib next below. Behind, the capsule is slightly continuous with the middle costo-transverse ligament, and in front it is thickened and overlaid by the stellate.

The *inter-articular ligament* consists of short strong fibres, which are closely interwoven with the outermost ring of the intervertebral substance, and at the head of the rib are attached to the transverse ridge between the segments of the articular facet. This ligament completely divides the articulation into two parts, each of which is provided with a perfect synovial sac. It does not brace the rib tightly to the spine, but is loose enough to permit a moderate amount of rotation upon its own axis. There is no inter-articular ligament in the costo-vertebral joints of the first, tenth, eleventh, and twelfth ribs.

The *stellate ligament* is the most striking of all, and is seen without any special dissection after cleaning the front of the column. It consists of bright white pearly fibres, which are attached to the upper and lower edges, and the whole of the intervening anterior or inner surface, of the neck of the rib a little way beyond the border of the articular facet of its head. From this they radiate upwards, forwards, and downwards, so as to form one continuous layer of distinct and sharply defined fibres; the upper ascend to the lower half of the lateral surface of the upper of the two vertebræ; the middle fibres run straight forwards to the intervertebral substance, and the lower descend to be attached to the upper half of the lateral surface of the body of the vertebra to which the rib belongs—*i.e.*, to whose number from above downwards it corresponds.

This ligament is overlapped at its attachment to the spine by the lateral portion of the anterior common ligament, and at its upper border by the communicating fibres between the anterior and posterior common vertebral ligaments.

Like the capsular, the stellate ligament checks the hinge-like movements of the head of the rib upon the bodies of the vertebræ. The inter-articular ligament, upon which the movements take place, allows more freedom than if the head turned directly upon its transverse ridge; while at the same time it retains the ridge in due relation to the intervertebral substance, and the synovial sacs above and below it. It should be observed that the synovial sacs are confined to the vertebræ and do not extend to the intervertebral substance, which acts as a buffer to break shocks; whilst the friction of movement occurs at the synovial cavities. All three of these ligaments assist the costo-transverse in retaining the rib in its place; but in this respect the stellate ligament serves a special function. Owing to the obliquely forward and inward slope of the articular surfaces, especially of those of the rib, as well as to the gradual narrowing of the bodies of the dorsal vertebræ from behind forward, there is a constant tendency, more especially in inspiration, for the head of the rib to glide forwards. The stellate ligament prevents this forward displacement, sometimes by its whole width, but sometimes by its upper fibres chiefly, and at others by its lower. The lower fibres form the broadest and largest portion of the ligaments, and prevent the undue elevation of the rib in inspiration; the upper fibres are rendered tense when the lower fibres are relaxed by the depression of the rib. In resisting the descent of the ribs in forcible expiration, the upper part of the stellate is aided by the superior costo-transverse ligament.

Another purpose served by the stellate ligament is to act as a bond of union between the contiguous vertebræ and the intervening substance. The ribs are like lateral wings or buttresses to the spine, and the fibres of these stellate ligaments pass off from them to three distinct pieces of the column, and thus add materially to the security of the whole.

The SYNOVIAL MEMBRANE forms two closed sacs, which do not communicate with each other; one for the part of the costo-vertebral articulation above, and another for the part below, the inter-articular ligament.

In the first, tenth, eleventh, and twelfth articulations there is but one sac, as these joints are undivided.

ARTERIES.—Branches spring from the intercostal arteries before they give off their posterior branches, some of which ascend to the joint above, others descend to the joint below, and after piercing the stellate and capsular ligaments reach the synovial membrane of the articulation.

NERVES.—Twigs are derived from the anterior primary branches of the spinal nerves in the immediate neighbourhood of the joints.

MOVEMENTS.—The costo-central articulations are ginglymoid in character, and the movements are limited to a slight degree of elevation and depression around an obliquely horizontal axis, corresponding with the inter-articular ligament; and to a slight amount of forward and backward gliding. The cavity of each hinge (with certain exceptions before alluded to) is formed by the adjacent bodies of two vertebræ and the intervening inter-vertebral substance, and in this cavity the head of the rib moves in the manner described, with occasionally a slight degree of rotation, or screwing movement.

There is considerable difference in the degree of mobility of different ribs, for while the first rib is almost immovable, except in very deep inspiration, and the second rib is but slightly movable, the mobility of the others increases from the second to the last: the two floating ribs are the most movable of all.

The head of the rib is the most fixed point of the costal arch, and upon it the whole arch rotates; the inter-articular ligament is so short that it allows only a very limited amount either of flexion and extension (*i.e.*, elevation and depression), or of gliding, and the gliding is further checked by the strong stellate or anterior costo-central ligament.

In inspiration, the rib is elevated and glides forwards in the cavity of the vertebræ; too great elevation is checked, not only by ligaments, but by the overhanging upper edge of the cavity itself. In expiration, the rib is depressed and glides back again in its cavity.

Although the range of movement at these and the other points of the thorax is very limited, the movements themselves are very regular and incessant. Sleeping or waking, in health and in disease, while respiration goes on, these joints are in use; yet they are seldom the seat of disease, and are but little exposed to injury from violence of any sort.

The Costo-transverse Articulation.

Class, Diarthrosis. *Subdivision*, Arthrodia.

The costo-transverse articulation, or the connexion between the neck and tubercle of the rib and the transverse processes of two vertebræ, consists of a synovial cavity surrounded by a capsular ligament, and of two other ligaments (the middle and posterior costo-transverse) between each rib and the vertebra to which it belongs; and of one ligament, the superior costo-transverse ligament, between the rib and the vertebra above it. Thus, *e.g.*, the second rib is connected with the transverse process of the second dorsal vertebra by means of a capsular ligament, a middle and a posterior costo-transverse ligament; and with the transverse process of the first rib by a superior costo-transverse ligament. So with the other ribs to the tenth inclusive.

The first rib has no superior costo-transverse ligament, *i.e.*, no bond of union with the seventh cervical; but its connexion with its own vertebra is the same as that of the others. The eleventh and twelfth ribs having no tubercle, and the eleventh and twelfth dorsal vertebræ having only rudimentary transverse processes, there is no synovial articulation, and no capsular or posterior costo-transverse ligament. There is a rudimentary middle costo-transverse ligament between the back of the neck of these ribs, and the rudimentary transverse process of the eleventh and twelfth dorsal vertebræ; and a well-marked superior costo-transverse ligament connects the eleventh and twelfth ribs with the transverse process of the tenth and eleventh vertebræ respectively.

THE VERTEBRÆ.—The transverse processes of the dorsal vertebræ vary in height with reference to the pedicles of their respective bones; those of the upper vertebræ are on the same horizontal level, those of the lower are somewhat below the level of the corresponding pedicles. This agrees with and explains the descent of the lower ribs as they pass outwards and forwards from the spine. It also accounts for the articular facets of the lower transverse processes being seated upon their upper borders, and of the articular facet on the tubercle of the lower ribs being situated on their lower sides, and looking obliquely downwards.

The processes of the upper ten dorsal vertebræ are long, truncated at their extremities, and slope considerably backwards as they pass in nearly horizontal planes outwards. They are each marked by a more or less circular facet, concave from side to side and from above downwards, and measuring usually from two-eighths to three-eighths of an inch in diameter; the facets of the middle vertebræ (fourth to eighth) are the largest and best marked. Above and behind the facet is a tubercle, and below and behind it is another, each of which adds to the bulbous outline of the extremity of the process.

THE RIBS.—The tubercle of the rib is prominent in the upper and middle ribs, but from the eighth downwards it is less so; and in the eleventh and twelfth it does not exist at all. In some of the ribs there appear to be two tubercles, but when this is the case it is the lower and inner one which has the facet upon it, while the other is but the rough projection for the posterior costo-transverse ligament, detached from the tubercle which it usually surmounts.

The facets are usually elongated horizontally, and are convex to fit into the concave facets of the transverse processes of the vertebræ. The facets in all the ribs are nearer to the lower than the upper margins of the tubercles, and become more and more so in the lower ribs. The short portion of the rib between the head and tubercle is the neck. It varies in different ribs; but averages from an inch to an inch and a half. It is longer in the upper ribs than in those below, and is absent in the eleventh and twelfth ribs. Though shorter in the middle than in the upper ribs, it is broader, and measures usually from half to five-eighths of an inch.

THE LIGAMENTS.—The *capsular ligament* is a loose fibrous envelope to the synovial membrane. Its fibres are attached to the bones beyond the margins of their articular facets, and are connected on the inner side with the middle, on the outer side with the posterior, and above with the superior costo-transverse ligaments. The capsular fibres are thickest below, where they are not strengthened by any other structure. It does not exist in the eleventh and twelfth ribs.

The *middle costo-transverse ligament* consists of very short fibres between the back of the neck of the rib and the front of the transverse process of the vertebra with which the tubercle articulates. It extends from the capsule of the costo-vertebral to the capsule of the costo-transverse joint, and limits all the movements of both joints. In order to expose this ligament, a horizontal section of the bones must be made or the rib must be forcibly detached from the transverse process.

The *posterior costo-transverse ligament* extends outwards and upwards from the extremity of the transverse process to the rough projection overhanging the facet on the tubercle of the ribs. Its fibres are short, but thick, strong, and broad. It limits movements both of inspiration and expiration, but it checks the ascent (*i.e.*, inspiratory movement) more effectually than it does the descent of the ribs.

The *superior costo-transverse ligament* has nothing to do with the vertebra with which the tubercle of the rib articulates, but passes to the transverse process of the vertebra above. The first rib has no such ligament. It presents a large anterior and a small posterior part. The anterior part forms by far the greater portion of the ligament, and consists of fibres which extend from the prominent ridge on the upper border of the neck of the rib, upwards and outwards to the lower border of the transverse process. The posterior portion is very small, being composed of a few scattered fibres which ascend inwards to the lower border of the transverse process; it limits the descent of the ribs in expiration. The anterior portion checks the downward movement of expiration, but it also prevents, like the middle costo-transverse, the separation of the neck of the rib from the transverse process of the vertebra below. They do not check the elevation of the ribs in inspiration, but they tend to prevent the rotation which accompanies and facilitates that elevation.

The anterior surface of this ligament is easily cleaned; the posterior surface and the posterior costo-transverse ligaments are dissected with difficulty, owing to the close adhesion thereto of muscular fibres.

ARTERIES.—The arterial twigs supplying the structures which unite the ribs and transverse processes are derived from the intercostal arteries, and from the branches of the posterior spinal vessels which supply the muscles of the back.

NERVES.—Twigs are derived from the posterior primary branches of the dorsal nerves.

MOVEMENTS.—The costo-transverse are *arthrodial* joints, and the movements which occur at them are limited to a gliding of the tubercle of the rib upon the facet of the transverse process. It has been stated that the exact position of the facet on the transverse process varies slightly from above downwards, being placed higher on the processes of the lower vertebræ. The plane of the opposed facets in most of the costo-transverse joints is, however, inclined upwards and backwards, so that the tubercles of the ribs glide backwards and upwards in inspiration, and downwards and forwards in expiration. The point round which these movements occur is the head of the rib; the tubercle of the rib glides upon the transverse process of the vertebra in the circumference of a circle, the centre of which is at the costo-central joint.

The Costo-chondral Joints, or the Union of the Ribs with their Costal Cartilages.

Class, Synarthrosis.

These joints are of the synarthrodial kind. The extremity of the cartilage is received upon the end of the rib, which is somewhat larger than the end of the cartilage. The two are joined together by a mere continuity of their investing membrane; the periosteum of one being continued into the perichondrium of the other, much in the same way as the epiphyses of bones are joined to their shafts.

It is probable, however, that the costal cartilages are not merely unossified portions of ribs, but that they are distinct parts of the skeleton separated, both from the sternum and from the ribs in fœtal life, by a formative material, which becomes converted into synovial membrane between certain cartilages and the sternum, but elsewhere usually disappears.

The Union of the Segments of the Sternum with one another.

The sternum is situated at the forepart of the thorax in the median plane of the body. It is connected with the costal arches by the first seven cartilages, and in addition gives support to the upper extremities at the sterno-clavicular joints. It is composed of five bony segments and an osseo-cartilaginous appendage, called the xiphoid cartilage, which together form a flat and symmetrical column. This column, like the vertebral column behind, gives support to the costal arches, completes the chest wall, and forms a sort of buckler to the thoracic viscera.

It is usual to speak of the sternum as consisting of the manubrium, body, and xiphoid or ensiform process; or in other words, of the præsternum, mesosternum, and metasternum, respectively.

The *manubrium* is the largest segment of the sternal column, at the summit of which it is placed. It is flat and somewhat triangular in shape, with its narrower end downwards. It is never, or rarely if ever, even in extreme old age, united with the body of the sternum by bone; but the two are connected together by intervening cartilage, and by a strong investing periosteum which is thickened by longitudinal ligamentous fibres, both behind and in front, as well as by the radiating and decussating fibres of the chondro-sternal ligaments. If this union be regarded as a joint it must be classed with the amphiarthrodial.

There is usually a well-marked curve with its convexity forwards in the sternal column opposite the union of the manubrium and body, and frequently there is a larger interval between these two segments behind than in front, so that the bones are there joined together by strong short bundles of fibrous tissue instead of by cartilage. Sometimes this fibrous tissue stretches forwards to the front of the column so as to give the appearance of two plates of cartilage, one for the manubrium and one for the body, united by means of short fibrous bundles.

The *mesosternum*, or body of the bone, consists of four segments which at the age of twenty-five years have usually united into one solid plate. Up to the time of their union by ossification a thin plate of cartilage intervened between the adjacent edges of the segments, and these were strengthened by the investing membrane and the longitudinal and radiating and decussating ligamentous fibres, like those referred to in the union of the manubrium and body.

The *metasternum or xiphoid process* is joined to the lower end of the body of the sternum by a thick investing membrane, by anterior and posterior longitudinal fibres, and by the radiating chondro-sternal ligaments of the sixth and seventh articulations. It is also connected with the fore surface of the sixth and seventh cartilages by the *chondro-xiphoid* ligament; and with the hinder surface of the seventh cartilage, for one-half or three-quarters of an inch, near the sternum, by means of some fine fibro-areolar tissue. The junction of the xiphoid with the lower end of the body of the sternum is on a level somewhat posterior to the junction of the seventh costal cartilage with the sternum. This union is synarthrodial.

MOVEMENTS.—The permanency of the soft union between the manubrium and body of the sternum is for the purpose of providing elasticity in the column, and so enabling it to resist external pressure rather than to permit of movements taking place between them.

At the junction of the xiphoid and sternum, a backward and forward movement of this appendage is constantly going on in respiration; and this is aided by the flexibility of the xiphoid itself. During the contraction of the diaphragm the ensiform or xiphoid process would be pulled backwards to a great extent were it not for the elevation of the sternum and costal arches, and the resistance offered by the descending viscera and by the chondro-xiphoid ligament.

During expiration, on the other hand, the diaphragm ceases to pull the process backwards, and it returns into its normal line with the sternum.

The Chondro-sternal Articulations, or the Ligaments and Joints which connect the Costal Cartilages with the Sternum.

Class, Diarthrosis. *Subdivision*, Ginglymus. (Joint of first cartilage excepted, which belongs to class Synarthrosis.)

There is no uniformity in the manner in which the cartilages articulate with the borders of the sternum. It varies in different individuals, and in different joints of the same individual, and also in the corresponding joints on the two sides of the body.

In the first joint, which is an example of synarthrosis, there is little or no movement. The first costal arch is needed to support the manubrium sterni, and through it the clavicle and the upper limb. It is the *point d'appui* from which the movements of the lower true ribs take their start.

In each of the other six joints there is a synovial cavity which in some instances is divided into two by an inter-articular ligament.

THE STERNUM.—We are concerned only with the lateral borders of this bone. The average length in the adult is about six inches and a half (inclusive of the xiphoid cartilage, which is about an inch long). Its width varies in different parts, being greatest between the cartilages of the first rib, where it measures from two to two and a half inches; and, if the xiphoid cartilage be excluded, its narrowest part is between the second costal cartilages or in the interval between the second and third, where it measures about three-quarters of an inch. The bone presents along each lateral border seven facets for as many costal cartilages, and in the recent state each facet is coated with a layer and sometimes a very thick layer of articular cartilage.

The superior facet is the largest and longest of all; it is oval in shape, but much narrower from before backwards at its lower part than above. It is overhung in front and above by a prominent lip or margin, which separates it from the oval articular surface on the upper border for the clavicle. This lip serves to prevent the upward and forward displacement of the first costal arch during the action of the muscles which play upon it; it also prevents the backward displacement of the sternum by violence. Below this facet the border of the sternum slopes rapidly from above downwards and inwards to the narrowest part of the bone, and then succeed at irregular intervals six shallow cavities for the cartilages of the second, third, fourth, fifth, sixth, and seventh ribs. The upper three of these cavities or facets are about an inch from one another, and that for the second cartilage is about the same distance from the facet for the first. The upper edge of each of these facets is more prominent than the lower, and the front is more prominent than the posterior, for the same purpose as in the case of the first.

The lower three facets are much nearer to each other; thus the fifth is about half an inch from the fourth, the sixth about a quarter of an inch from the fifth, and the seventh less than one-eighth of an inch from the sixth. The fifth facet is slightly overhung above and in front by its margin, but to a less extent than those higher than it. The sixth and seventh, especially the seventh, are situated more at the lower angle of the body of the sternum than on the lateral border. The lower end of the body widens out a little, and in the centre of its inferior border the xiphoid cartilage unites with it; while on each side of the union with the xiphoid cartilage the costal cartilages of the seventh and sixth ribs are close together. Thus these cartilages also are overhung by bone above, at their union with the sternum, but by the sternal body, and not by an outstanding margin of the articular facet.

The third, fourth, and fifth cartilages articulate with the body of the sternum, in the line of union of two of its primitive segments; the second, at the line of union of the manubrium with the body; the seventh, at the line of union of the body with the xiphoid cartilage. The sixth is not related to two segments, but articulates at the angle between the lateral and the inferior borders of the body of the bone. The intervals between the facets are somewhat concave, and correspond to the intercostal spaces.

There is, it will be observed, considerable analogy between the mode in which the costal arches are connected with the sternal and vertebral columns. Thus each cartilage, except the first and sixth, is united with two segments of the sternal column as the head of each rib is with two vertebræ, while the articular facets of both sternal and vertebral column are overhung above, so as to prevent the upward displacement of the arches by the pull of the muscles of inspiration, and for the same reason a strong stellate or radiating ligament passes over the front of both vertebral and sternal joints. The analogy, moreover, is carried out in the case of the first costal arch, which is connected with only one vertebra behind, just as it is with only one segment (the manubrium) of the sternum in front.

The Costal Cartilages have, by some anatomists, been regarded as the anterior epiphyses of the ribs. Like the ribs, they differ from one another, thus they increase in length to the seventh, and decrease from the eighth to the twelfth. They decrease in thickness from the first to the twelfth.

The *first* descends to the sternum, in continuation of the direction of the first rib. Its inner extremity is directly united with the osseous tissue of the sternum, so as to afford strong support to the clavicle, and by giving attachment to the costo-clavicular ligament the cartilage adds to the security of the sterno-clavicular articulation.

The *second cartilage* joins the sternum at a right angle, and is of nearly the same width throughout. It forms an obtuse angle with its own rib. The sternal extremity is very convex from above downwards, and its articular facet is divided by a horizontal ridge into two parts, one of which looks upwards to articulate with the lower angle of the manubrium, and the other downwards to articulate with the superior angle of the body of the sternum.

The *other cartilages*, as low as the tenth, make, each one in succession, a more acute angle with the rib than its predecessor;

for as the ribs are inclined downwards and forwards from their vertebral joints, with an obliquity increasing from the first to the last, so the costal cartilages have to ascend with a corresponding degree of obliquity from their junction with their ribs to their sternal joints or anterior free extremities. Each is shallower at its anterior end than elsewhere, as they diminish in width from their costal extremity forwards. The articular facets at the anterior extremity of the third, fourth, fifth, sixth, and seventh are slightly convex from above downwards, and play in the corresponding cavities on the lateral border of the sternum.

THE LIGAMENTS.—Except at the synarthrodial joint between the first cartilage and the sternum, each of the chondro-sternal articulations has an anterior and a posterior, a superior and inferior chondro-sternal ligament, which together form a complete capsule. A synovial cavity lines the joint, and is commonly in the second, and occasionally in one or more of the third, fourth, fifth, and sixth joints, divided into two parts by an inter-articular ligament.

The *anterior chondro-sternal ligament* is a triangular layer of strong fibres which covers the inner half inch of the front of the cartilage, and radiates upwards and downwards upon the front of the sternum. Some of the fibres decussate across the middle line with the fibres of the corresponding ligament of the opposite joint; while along the upper and lower borders of the ligament they are in contact with the superior and inferior chondro-sternal ligaments respectively.

By the lower part of this ligament, traction is made upon the sternum during the act of inspiration; the downward and inward obliquity of the fibres allows them to pull upon and raise the sternum during the elevation of the ribs. It is obvious, however, that apart from this obliquity the mere connexion of the cartilages with the sternum by means of facets with overhanging upper edges would insure the elevation of the sternum, together with the costal arches.

The *posterior chondro-sternal ligament* consists of little more than a thickening of the fibrous covering of the bone and cartilage; indeed, it may be fairly said that these joints are completed behind by a continuity of the perichondrium into the periosteum.

The *superior and inferior chondro-sternal ligaments* are strong and well-marked bands of fibres extending over the borders of the joints from the front to the posterior surface. In the case of the second, third, fourth, and fifth they are reflected some distance along the curved lateral border of the sternum at the intercostal intervals.

The sixth and seventh joints are so close together that the articular cartilage on the sternal facets is continuous, and the inferior ligament of the sixth and the superior of the seventh are blended together, so as to form a kind of inter-articular ligament between the two separate joints.

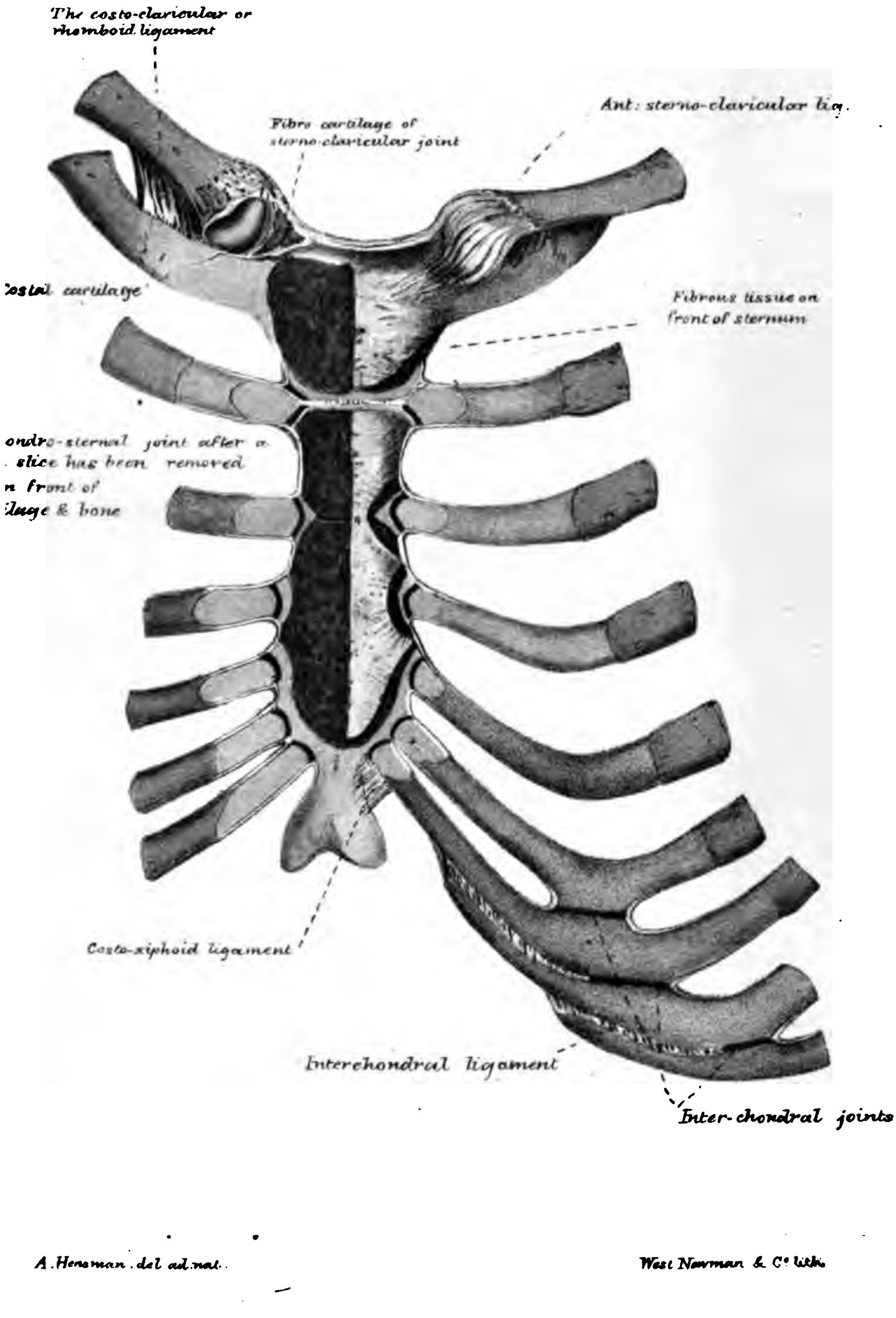
Deeper than the fibres of these several ligaments are some shorter ones connecting the margins of the articular cartilage on the sternal facets with the edges of the facets of the costal cartilages. They are generally most distinct at the front and lower part of the joint, and in some cases are so numerous, and encroach so considerably upon the synovial cavity, that they reduce it to a very small size, or almost obliterate it. The sixth and seventh, but especially the seventh, are the joints most frequently modified in this manner.

The *inter-articular ligament* is by no means a constant constituent of the chondro-sternal joints. It is usually present in the second joint on one, if not on both sides of the same subject. It consists of a strong transverse bundle of short fibres between the ridge on the facet of the cartilage and the symphysial substance between the manubrium and the body of the sternum. Sometimes the part of the synovial cavity above this ligament is almost replaced by fine ligamentous fibres, in the same way that the synovial cavity of one or other of the joints below is sometimes nearly or quite obliterated.

The *chondro-xiphoid ligament* is a strong flat band of fibres passing obliquely upwards and outwards from a considerable part of the front surface of the xiphoid cartilage to the anterior surface of the sternal end of the seventh costal cartilage, and most frequently to that of the sixth also.

It has an important action besides helping to unite the seventh costal cartilage to the sternal column; for it fixes the xiphoid cartilage during the elevation of the sternum and costal arches in inspiration, and thus prevents it from being drawn backwards to any great extent during this movement by the contraction of the diaphragm, which occurs at the same moment as the elevation of the chest wall.

VERTICAL SECTION OF CHONDRO-STERNAL & INTERCHONDRAL JOINTS


The costo-clavicular or rhomboid ligament
Fibro cartilage of sterno-clavicular joint
Ant: sterno-clavicular lig.
ostal cartilage
Fibrous tissue on front of sternum
ondro-sternal joint after a
slice has been removed
n front of
ilage & bone
Costo-xiphoid ligament
Interchondral ligament
Inter-chondral joints

A. Hensman. del. ad. nat.

West Newman & Co. lith.

ARTERIES.—The anterior or perforating branches from the internal mammary artery ramify over the front of the joints, and supply them.

NERVES.—Twigs are supplied from the anterior extremity of the upper intercostal trunks.

MOVEMENTS.—Most of the chondro-sternal are ginglymoid joints. The movement permitted at them is very limited, but consists of a hinge-like action in two directions: first, there is a small amount of elevation and depression, which takes place round a transverse axis; and secondly, there is some forward and backward movement round an obliquely vertical axis. The depressions on the lateral borders of the sternum are the sockets or cavities of the hinge-joint, and into these the ends of the cartilages are received.

In inspiration the cartilage is elevated, and the lowest part of its articular facet is pressed into the socket of the sternum, and the sternum is thrust forwards, so that the upper and front edges of the opposed articular surfaces separate a little. In expiration the cartilage is depressed, and the sternum returns to its former position, so that the articular surfaces regain their former state of apposition. Thus the two extremities of the costal arches move in their respective sockets in opposite directions; for whereas in inspiration the hinge-like action at the head is such that the upper part of the articular facet rolls into the socket, the lower part of the articular end of the cartilage sinks a little deeper into its cavity on the sternum.

This difference results necessarily from the fact that the costal arch moves upon the vertebral column, and having been elevated, it in its turn elevates the sternum by pushing it upwards and forwards. Were this not the case the sternum would be depressed by the elevation of the costal arches.

The Inter-chondral Articulations, or the Union of the Costal Cartilages with one another.

Class, Diarthrosis. *Subdivision*, Arthrodia.

The anterior extremities of the lower five ribs are unconnected with the sternal column; and whilst the upper three of these are closely connected with one another and the seventh, each with the lower border of the preceding, by means of short fibro-areolar and muscular fibres, the two lowest are at some distance from the tenth, and from one another.

A little in front of the point where the costal cartilages bend upwards towards the median line the sixth is united with the seventh, the seventh with the eighth, the eighth with the ninth, and the ninth with the tenth. At this point each of the cartilages, from the sixth to the ninth inclusive, is deeper than elsewhere, owing to the projection downwards from its lower edge of a broad blunt process, which comes into contact with the upper edge of the cartilage next below. Each of the apposed surfaces is flattened and smooth, and connected together at their margins by ligamentous tissue, which forms a complete capsule for the articulation, and is lined by a synovial membrane.

The largest of these synovial cavities is between the seventh and eighth cartilages, and is five-eighths of an inch in width. Those between the eighth and ninth, and the ninth and tenth, are generally much smaller, as the flattened surfaces, instead of being free to play upon each other in the whole of their extent, are in part held together by the ligamentous tissue which extends between these surfaces at their anterior margins. Sometimes indeed fibrous tissue alone forms the bond of union between these lower cartilages, as it does occasionally between one or other of the costal cartilages and the sternum; in which case, of course, there is no synovial articulation.

In the interspaces between the cartilages, both in front of and behind the inter-chondral joints, are the muscular and fibrous tissues of the chest wall.

Sometimes the fifth and sixth cartilages are united together, like those below them.

The eleventh and twelfth cartilages are not in contact with the tenth and with one another, and therefore have no inter-chondral joint, but are connected only by the intercostal and abdominal muscles and areolar tissue.

ARTERIES.—The musculo-phrenic artery from the internal mammary supplies the structures of these small joints by means of the branches it sends outwards along the intercostal spaces.

NERVES.—Twigs are supplied from the intercostal nerves of the corresponding spaces.

MOVEMENTS.—By means of the costal cartilages and of this series of inter-chondral joints, strength with elasticity is given to the wall of the trunk at a part where the cartilages are the only firm structure in its composition, while at the same time a slight gliding movement is permitted between the costal cartilages themselves. This movement takes place round an axis which corresponds to the long axis of the cartilages; by it the outward projection of the lower part of the thoracic wall is increased in deep inspiration, and thereby more room is provided for the viscera of the abdomen. These viscera are compressed between the descending diaphragm and the upper part of the abdominal wall, which sinks in considerably towards the end of a long inspiration.

THE MUSCLES OF THE THORAX.—In all animals whose respiratory organs are contained within a true thoracic cavity, the framework of the thorax serves other purposes than those subservient to respiration, *i.e.*, the drawing in and the expulsion of air. In all it gives attachment to large muscles of the upper limb, whether they are used for prehension or locomotion; to muscles of the back for the extension of the trunk, and to muscles of the abdomen which act upon the trunk and pelvis. Thus it is evident that the muscles *connected with the thorax* are by no means synonymous with the muscles *of respiration.* As the thorax is part of the boundary of the trunk, it affords advantageous attachment for muscles which move the trunk as a whole, quite irrespective of the movements necessary for respiration. The muscles of respiration are destined *especially* to act upon the thorax so as to expand or contract its cavity; but there are a number of other muscles attached to the thorax destined *especially* for other ends than those of inspiration and respiration, which also do occasionally act to enlarge or diminish the cavity of the chest, and thus to increase the power of inspiring or expiring. These latter are sometimes spoken of as the *indirect muscles of respiration;* but in difficult inspiration patients are sometimes seen employing nearly their whole muscular apparatus, so that "scarcely any particle remains in the body which is not more or less concerned in the business of respiration."

In this sense the group of indirect respiratory muscles would nclude nearly every muscle in the body not included in the group of *direct muscles of respiration.*

In the following enumeration the muscles of the thorax are divided into the *direct*—or those whose sole or chief purpose is to act upon the costal arches; and the *indirect*—whose primary use is to move some distant part of the skeleton whilst acting from the thorax as their fixed point.

Most of the direct muscles of the thoracic wall are also intrinsic muscles of respiration, but not all. The sacro-lumbalis, longissimus dorsi, and musculus accessorius, for instance, are direct muscles of the ribs—*i.e.*, their chief purpose is to act upon the costal arches, but with the object of extending the trunk, not primarily with the view of aiding in respiration. These muscles afford another good illustration of what I have described as a general law—viz., that muscles which by their action upon bones near their articular surfaces would have the effect of straining the ligaments, or weakening the joints, unless they were attached to both bones of the articulation, do as a matter of fact give security to the joints by being inserted into both bones.

Part of the longissimus and the spinalis dorsi, the middle and inner columns of the erector spinæ, are inserted into the processes of the dorsal vertebræ, and in their action to extend the back are resisted by the weight of the thoracic and abdominal viscera, which by dragging upon the ribs and sternum tend to pull away the head and neck of the ribs from the spinal column.

These conflicting forces would unduly strain the costovertebral ligaments were it not for the outer column of the erector spinæ (sacro-lumbalis) and part of the longissimus dorsi, which by acting in conjunction with the rest of the erector and by being inserted into the ribs from the tubercles to the angles, assist in holding the ribs to the spinal column, at the same time that they act to extend the back.

But although the muscles of the back are not direct muscles of respiration, they—even those which have no attachment whatever to the ribs—assist inspiration. For inspiration to be full and complete, there must be extension of the spine. When the column is bent forwards the ribs fall together, and though ordinary and quiet inspiration goes on well for a time in this position, the column must be erect before the ribs can be separated to their fullest extent and a full inspiration made.

The long-continued effects of a curved spinal column upon inspiration is seen in the laboured and short breathing and in the deficient aëration of the blood in sufferers from spinal deformities; and explains the great relief experienced by patients from extension of the back in a fixed apparatus such as has of late been introduced into surgical practice by Dr. Sayre, of New York.

Again, those portions of the muscles of the back which are inserted into the ribs depress the costal arches when the pelvis and spine are fixed, and thus occasionally assist in, and therefore are indirect muscles of, expiration.

The *direct* muscles of the thorax—*i.e.*, those whose chief purpose is to act upon the costal arches, whether for the purposes of respiration or otherwise—may be divided into two groups; (A) those which arise beyond the thorax, and are only inserted into it; and (B) those which are not connected with any other part of the skeleton except the thorax.

A. Those which arise beyond the thorax, are—

1. The serratus posticus superior.
2. The serratus posticus inferior.
3. The scalenus anticus, scalenus medius and scalenus posticus.
4. The sacro-lumbalis and longissimus dorsi.
5. The quadratus lumborum.

Of these only the serrati postici are purely muscles of respiration, the rest serve other purposes as well; while the scaleni and the quadratus lumborum act occasionally upon the neck and pelvis respectively.

The *scalene* muscles are elevators of the first two costal arches, and aid constantly in the movements of inspiration, not only by their own direct action upon the ribs, but by fixing the arches to which they are connected, and thus making them the "point d'appui" from which the intercostal muscles act.

The *sacro-lumbalis, longissimus dorsi, and quadratus lumborum* serve mainly to extend the trunk, but together with the serratus posticus inferior they depress the lower ribs and thereby aid indirectly in inspiration. During the action of the diaphragm its circumferential muscular portion tends to pull upwards and inwards the lower six ribs from which it arises towards its own central inelastic tendon, but this tendency is counteracted by these several muscles (as well as by the descending viscera), which give firmness to the costal arches by depressing them ; just as the scalene muscles and the serratus posticus superior give firmness to the superior arches by elevating them.

These same muscles of the back also aid in forcible expiration, by depressing the ribs to which they are attached. This they do by continuing their action after the diaphragm has ceased to contract.

B. Those which both arise from and are inserted into the thorax.

1. The subcostales and the triangularis sterni, the former near the angles of the ribs, and the latter at the costal cartilages from the sixth to the second inclusive, depress the costal arches and thereby aid directly in forcible expiration.
2. The diaphragm, the chief muscle of respiration.
3. The intercostales, muscles of inspiration.
4. The levatores costarum, muscles of inspiration.
5. The musculus accessorius ad sacro-lumbalem.

All the muscles in this group, excepting the last, are simply and purely muscles of respiration.

The diaphragm is concerned in a large number of physiological processes, and aided more or less by the other respiratory muscles, contributes to such acts as coughing, sighing, singing, sneezing, sucking, whistling, yawning, vomiting, talking, as well as defecation and micturition.

The musculus accessorius, it is true, assists in expiration by approximating the upper and lower ribs towards one another, but its chief purpose is to co-operate with the other muscles of the back in extending the trunk.

It also acts, however, with those muscles to produce forcible expiration. The fullest inspiration that is possible is made in the erect posture, but hyperextension of the back diminishes the capacity for inhaling, and is attended with some involuntary expiration if made immediately after a full breath has been taken in the erect attitude. This is doubtless due to the depression of the ribs by the extreme contraction of the sacro-lumbalis and longissimus dorsi, and to the approximation of the ribs by the musculus accessorius which acts at the same time.

The *indirect muscles* of the thorax have one of their attachments at the thorax and the other at some remote part of the skeleton, and their chief action is not to move any part of the thorax, but to act from it as their fixed point. They may be grouped according to the division of the body which they act upon.

(*a*) *Those to the upper limb*—

1. The pectoralis major; 2. Pectoralis minor; 3. Subclavius; 4. Serratus magnus; 5. Latissimus dorsi.

The last-named has but a slight connexion with the thorax, being attached only to the three lowest ribs. All these muscles act secondarily upon the thorax, and serve to draw upwards or forwards the trunk when the outstretched arms are made the fixed point, as in climbing or pulling. The pectoralis major and minor, and the subclavius, occasionally act as assistant muscles of inspiration. The pectoralis major affords another good illustration of the law above referred to respecting the attachment of muscles to both bones of an articulation.

The serratus magnus, at first sight, might seem to contradict this law; but not so, for not only is it attached to the ribs at some distance from either extremity, but it pulls upon a very movable part of the skeleton, viz., the scapula, and in an oblique direction, so that it in reality exerts no influence to disturb the joints of the costal arches.

Again, the law is illustrated by the abdominal muscles. The opposite direction of the fibres of the external and internal oblique, and the position of the transversalis upon the inner surface while the external oblique arises from the outer surface of the costal arches, neutralise one another. The rectus abdominis is attached to the sternum, cartilages, and ribs, and therefore acts simultaneously upon all.

(*b*) *To the spine*—

The cervicalis ascendens, which takes origin from four or five of the upper ribs, acts in conjunction with the rest of the erector spinæ muscles and extends the neck. It has little if any independent action on the thorax.

(*c*) *To the head anteriorly, and to the larynx*—

1. The sterno-cleido-mastoid.

2. The sterno-thyroid, and generally the sterno-hyoid. All these muscles act from the sternum upon the parts into which they are inserted. They may assist in fixing or raising the sternum for the purposes of respiration, but this only rarely.

It is interesting to remark that while the sterno-mastoid muscle is attached both to the sternum and clavicle in illustration of the law above stated, yet that the sterno-hyoid and sterno-thyroid, being small feeble muscles and acting upon a very movable part like the larynx and hyoid bone, are not invariably attached to the bone on each side of the joints near which they arise, for the reason no doubt that their pull upon the sternum is not sufficient to exert any deleterious effect upon the articulations.

(*d*) *To abdominal wall*—

1. The obliquus externus; 2. The obliquus internus; 3. The transversalis; and 4. The rectus abdominis.

These muscles form the greater part of the wall of the abdomen, and compress the viscera of that cavity as well as the viscera of the pelvis.

When the vertebral column is fixed, they are able to draw down the ribs and to assist in forcible expiration by contracting the lower portion of the thorax, and forcing up the viscera against the diaphragm.

When the column is not fixed, they pull upon the thorax, and thereby bend the trunk forwards and downwards or laterally and downwards.

MOVEMENTS OF THE COSTAL ARCHES AND THE STERNUM AS A WHOLE.—Before describing the movements of the thorax as a whole, it must be premised that there are some few modifications in the movements of certain ribs which result from the peculiarities in the shape of those ribs. Thus the first rib (and to a less extent the second also), which is flat on its upper and under surfaces and is placed at the upper end of the thorax, revolves on a transverse axis which passes through the costo-transverse and costo-vertebral joints, and coincides pretty nearly with the axis of movement of the corresponding rib of the opposite side. During inspiration and expiration these costal arches with the sternum between them play up and down in such a manner, that while the transversely elongated tubercles of the ribs move upon the depressed sockets on the transverse processes in a hinge-like manner, the rounded heads of the ribs are moving similarly, but with a slight screwing or rotation in their sockets, and the anterior extremity of these costal arches are simply raised and depressed.

The other ribs, more particularly those in the mid-region of the thorax, move in a somewhat more complex manner. Besides the elevation of their anterior extremities, the bodies and angles of the ribs rise nearly as much in inspiration as these extremities themselves, and the whole costal arch revolves upon an axis drawn from before backwards from the costo-central to the chondro-sternal articulations. This axis corresponds in the former joints to the oblique ridge on the head of each rib. It is incorrect to say that the rotation takes place upon a line connecting the two extremities of the rib itself.

Without this difference the movements of the ribs of the mid-region of the thorax would not have increased the transverse diameter of the chest to so great an extent, and consequently would not have rendered the same assistance in inspiration.

In conformity with this difference the movement of the tubercles of the ribs upon the transverse processes is one of gliding upwards and backwards in inspiration, and downwards and forwards in expiration; and for this purpose the apposed articular surfaces at these costo-transverse joints are flat and a little elongated from above downwards.

During inspiration the movements of the thorax enlarge in every direction the space surrounded by it. The antero-posterior diameter is increased by the forward movement of the sternum, and by the elevation of the costal cartilages and of the forepart of the ribs, whereby they are brought to nearly the same level as the heads of the ribs. The transverse diameter is increased both anteriorly and posteriorly. When at rest the middle part of the ribs themselves dips considerably, owing to a downward curve in their body in front of the angle, and is thus on a lower level than either the costo-vertebral or the chondro-sternal articulation. Owing to this obliquity, when the rib is raised the transverse diameter of the chest is increased, and the increase is proportionate to the degree of obliquity which is greatest in the ribs in the mid-region of the thorax.

Further forward the anterior extremity of the rib is not only elevated and advanced, it is also carried a little outwards from the median line. Thus the transverse diameter is increased behind by the elevation of the middle part of the ribs, and in front by the abduction of their anterior extremity; and it is throughout further increased by the outward roll of the lower border of the costal arch in its rotation upon a line drawn between the vertebral and sternal joints.

The increase in a vertical diameter is due to the elevation of the ribs, especially of the upper ones, and to the consequent widening of the intercostal spaces. The descent of the diaphragm, however, chiefly increases the " cavity of the thorax" in the vertical direction.

It will be seen that the dorsal vertebræ take no share in this general increase in the size of the thorax; they act like a fixed rod or column, which only occasionally, during forced inspiration, becomes extended to a slight degree. After the vertebræ, the sternum is the next least movable part of the thorax, and the part of the thoracic area intervening between them does not need to undergo such great variations in size, owing to the nature of the contents of the mediastinum, which instead of being lung, are the heart and great vessels, the œsophagus, areolar tissue and glands.

The greatest increase, both in a transverse and antero-posterior direction, takes place at those parts of the thorax which are themselves of the greatest extent—*i.e.*, where the ribs are longest, most oblique, and most curved at their angle; and where the bulkiest portion of the lung is enclosed. This is on a level with the sixth, seventh, and eighth ribs. Moreover, the hinder portion of the costal arches—*i.e.*, about the angle of the ribs—by their movements cause the greatest increase in the thoracic measurement, and in this part the thickest and most active and important part of the lungs are contained.

At the lower part of the thorax, where the ribs have no relation to the lungs, and do not affect respiration directly by their movements, it is important that the costal arches should be well thrown outwards in order that thereby they may counteract the disadvantageous effect upon the contraction of the diaphragm, which would be otherwise sustained by their elevation. By widening the lower part of the thorax during inspiration the origin of the muscular fibres of the diaphragm is widened, and their power is thus increased.

The muscles by which the various movements of inspiration are effected have been enumerated above. For the diversity of views respecting the action of the intercostal muscles, standard works on anatomy of the thorax may be referred to. Here it is sufficient to state, that both external and internal muscles are regarded by the author as muscles of inspiration. Ordinary expiration is not produced by muscular action, but is a return of parts to their state of rest after they have been disturbed therefrom by the muscles of inspiration.

PART III.

THE LIGAMENTS AND JOINTS OF THE UPPER EXTREMITY.

CHAPTER IX.

THE STERNO-CLAVICULAR JOINT AND COSTO-CLAVICULAR LIGAMENT.

Class, Diarthrosis. *Subdivision*, Arthrodia.

AT this joint the inner and larger end of the clavicle is united to the superior angle of the manubrium sterni. The first costal cartilage, moreover, assists the sternum in giving support to the clavicle. Looking at the bones, one would say that they were in no way adapted to articulate with one another, and yet they assist in constructing a joint of great strength, security, and importance. It is true that the bones themselves are nowhere in actual contact, being separated completely by the inter-articular ligament. The sterno-clavicular is the only articulation between the upper limb and the trunk, and takes part both in the upward and downward, and in the forward and backward movements of the arm, as well as in the movements of circumduction of the upper extremity. It is an arthrodial joint. The interval between the joints of the two sides varies in different subjects from an inch to an inch and a half.

The STERNUM presents at the superior angle of the manubrium a large concave articular facet looking upwards, outwards, and a little backwards. Its longest diameter is, in the transverse direction, from within outwards, and measures rather over three-quarters of an inch. Its antero-posterior diameter is less than half an inch, and is wider near the notch of the sternum than near the first chondro-sternal joint. It is markedly, but irregularly, concave from above downwards and outwards, and is often concave from before backwards also. Occasionally, owing to the bevelling off of the articular surface near to its anterior and posterior margins, the socket looks to be very slightly convex from before backwards, but even then the centre of the socket is always the deepest part of it. The margin of the facet is sharply defined all around, but is apparently more projecting in front, owing to the backward inclination of the facet. Looking at the bone from in front none of the articular surface can be seen, whereas looking from behind the entire facet is in view.

This obliquity has importance in relation to the movements of the thorax in respiration, rather than to those of the upper extremity; by this backward slope of the facet the sternum is able to advance a little upon the end of the clavicle during its elevation in inspiration; had the slope of the facet been forward, the upper end of the manubrium must have tilted backwards upon the end of the clavicle, at the same time that the body of the sternum was raised and advanced by the inspiratory muscles. The interval between the facet on the two sides varies much more in different subjects than does the size of the facet itself. In some subjects this space, which corresponds with what is called the sternal notch, is not wider than three-quarters of an inch, in others it exceeds an inch. The depth of this notch is considerably increased by the inner end of the clavicle, so that it is much greater in the living subject and the articulated skeleton than would be supposed from an examination of the manubrium alone. This notch is also called the inter-clavicular notch.

Immediately below the facet for the clavicle is the junction of the cartilage of the first rib with the manubrium. This is a synarthrodial joint, the two structures being directly united with one another. The cartilage on its way from the rib to the manubrium slopes downwards as well as forwards; and as it is so inclined that its upper surface looks forwards and its under surface backwards, the posterior border is the highest part of it. It is this border which increases considerably the concavity of the sterno-clavicular socket, the lower and outer part of which it completes. Indeed the two form together the arc of a circle, the diameter of which is about an inch, and may be roughly stated to be the horizontal line drawn between the upper border of the sternum and the first costo-chondral joint. It is upon the inner three-fourths of this arc that the clavicle moves.

THE CLAVICLE.—The inner two-thirds of the shaft of the clavicle is strongly curved in a horizontal plane, with the convexity of the curve forwards, and presents a marked difference from the outer one-third, in that it is cylindrical in outline instead of being flattened on its superior and inferior aspects. At the inner end the bone suddenly enlarges, like the extremities of the shaft of many of the long bones, into an articular surface; this is for the sternum, or, more properly speaking, for the inter-articular ligament of the sterno-clavicular joint, and it faces almost directly towards the middle line of the body. The ligament corresponds in shape, direction, and size to the extremity or base of the clavicle, which is not the case with the socket upon the sternum. Unless the arm is raised above the shoulder only the lower portion of the inner or sternal end of the clavicle rests on the sterno-clavicular socket, and this only upon that part of the socket which is immediately above and internal to the union of the first costal cartilage with the sternum. Between the rest of the articular surfaces at the sterno-clavicular joint there is a V-shaped interval, which is occupied by the inter-articular fibro-cartilage and the synovial sacs, and is tightly bound over by the inter-clavicular ligament. The articular surface at the inner end of the bone is triangular in outline, and of its three borders or margins one, the anterior, is nearly vertical; another, the inferior, is nearly horizontal, and extends from before backwards and inwards; while the third, the posterior, slopes downwards and backwards to meet the inferior border at the rounded apex behind. The angles of this triangular surface are well rounded, its base is above and in front, and its apex behind and below. The surface is convex from above downwards in its posterior portion, and sometimes throughout its extent; but usually there is a depression near its centre which makes it somewhat cup-shaped in the dry state. When deprived of its articular cartilage it is generally very rough and uneven, excepting below, where it rests upon the sternum. Here it is faceted and smooth; and frequently this faceted surface extends not only from the apex behind to the anterior vertical border of the extremity in front, but reaches also along the under surface of the shaft as far as the clavicle rests upon the upper border of the first costal cartilage.

The circumference of the inner end of the clavicle varies from two and a half to three and a half inches; its longest diameter is from above downwards, backwards, and a little inwards, and varies from three-quarters of an inch to one and one-third of an inch; its shortest diameter is from before backwards at its lowest part, where the bone tapers to a rounded apex. Where the shaft begins to enlarge into the extremity the bone is rough and raised, more especially at the back and lower aspects, for the purpose of giving secure attachment to the strong ligaments which surround the articulation; and where the posterior passes into the inferior surface of the shaft, a little external to the apex of the articular extremity, there is a rough tubercle often prolonged into a ridge—the rhomboid tubercle or ridge—for the attachment of the costo-clavicular or rhomboid ligament.

THE LIGAMENTS.—The ligaments of this joint have been always described as four in number, in addition to the inter-articular fibro-cartilage—viz., the anterior and posterior sterno-clavicular, the inter-clavicular, and the rhomboid or costo-clavicular. This description is, however, somewhat forced, for there is no distinction of what may most correctly be called the capsular ligament of the joint into anterior and posterior portions.

The Capsular Ligament.—Ligamentous fibres, taking varying directions, and of various strength and thickness, completely surround the articulation, so as to form a capsule; and as they pass between the margins of the articular surfaces are firmly connected with the edges of the inter-articular cartilage. The fibres at the back of the joint—the *posterior sterno-clavicular ligament*—are stronger than those in front or below; the more superficial set passes from the manubrium sterni on the median side of and below the sternal facet, outwards and upwards to the clavicle, many of them being attached to the projecting posterior edge of the inner extremity of the clavicle, while a few are prolonged onwards upon the posterior surface of the bone, where they blend with the periosteum. The deeper fibres, more especially those at the posterior inferior angle of the joint, which are very thick and numerous at their clavicular attachment, connect the inter-articular cartilage with the clavicle and with the sternum without passing between the sternum and the clavicle. This portion of the capsule checks the forward movements of the clavicle on the sternum. The fibres in front of the joint—*the anterior sterno-clavicular ligament*—are well marked, but more lax and less tough than vexity of the curve forwards, and presents a marked difference from the outer one-third, in that it is cylindrical in outline instead of being flattened on its superior and inferior aspects. At the inner end the bone suddenly enlarges, like the extremities of the shaft of many of the long bones, into an articular surface; this is for the sternum, or, more properly speaking, for the inter-articular ligament of the sterno-clavicular joint, and it faces almost directly towards the middle line of the body. The ligament corresponds in shape, direction, and size to the extremity or base of the clavicle, which is not the case with the socket upon the sternum. Unless the arm is raised above the shoulder only the lower portion of the inner or sternal end of the clavicle rests on the sterno-clavicular socket, and this only upon that part of the socket which is immediately above and internal to the union of the first costal cartilage with the sternum. Between the rest of the articular surfaces at the sterno-clavicular joint there is a V-shaped interval, which is occupied by the inter-articular fibro-cartilage and the synovial sacs, and is tightly bound over by the inter-clavicular ligament. The articular surface at the inner end of the bone is triangular in outline, and of its three borders or margins one, the anterior, is nearly vertical; another, the inferior, is nearly horizontal, and extends from before backwards and inwards; while the third, the posterior, slopes downwards and backwards to meet the inferior border at the rounded apex behind. The angles of this triangular surface are well rounded, its base is above and in front, and its apex behind and below. The surface is convex from above downwards in its posterior portion, and sometimes throughout its extent; but usually there is a depression near its centre which makes it somewhat cup-shaped in the dry state. When deprived of its articular cartilage it is generally very rough and uneven, excepting below, where it rests upon the sternum. Here it is faceted and smooth; and frequently this faceted surface extends not only from the apex behind to the anterior vertical border of the extremity in front, but reaches also along the under surface of the shaft as far as the clavicle rests upon the upper border of the first costal cartilage.

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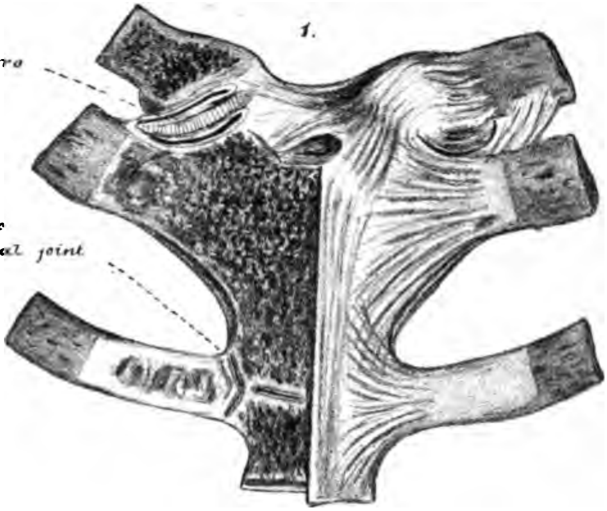
The superior portion of the capsule consists chiefly of short tough fibres passing from the sternum to the inter-articular cartilage, and of others welding this cartilage to the upper border of the extremity of the clavicle, while only a few pass over the joint from the upper edge of the sternum to the upper surface of the clavicle.

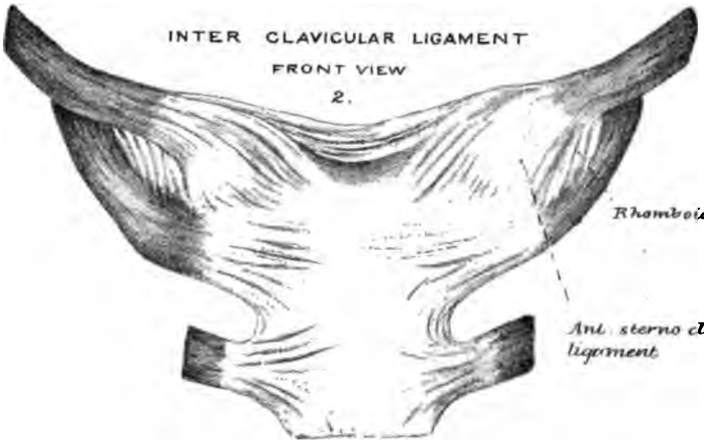
The Inter-clavicular Ligament.—The most prominent and conspicuous of. the ligaments of the sterno-clavicular joint is one common to the joints of the opposite sides, which thickens and strengthens materially the superior portion of the capsular ligament of each joint—the inter-clavicular ligament. Its fibres form a strong concave band along the posterior aspect of the upper border of the manubrium, nearly a quarter of an inch deep, with its concavity upwards, and its upper border tapering to a narrow, almost sharp edge. It is connected with the posterior superior angle of the inner extremity of each clavicle, and with the fibres which weld together the inter-articular fibro-cartilage and the clavicle, and it then passes across from clavicle to clavicle above the sternum, to which it is attached on its anterior aspect, only by means of a thin membranous layer which covers it and the periosteum of the front of the sternum. Posteriorly the lowest fibres are slightly attached to the sternum, and are continuous with the posterior sterno-clavicular fibres of the capsule of each joint. It prevents the upward displacement of the clavicle during forcible depression of the arm or shoulder.

The *rhomboid or costo-clavicular ligament* is a dense strong

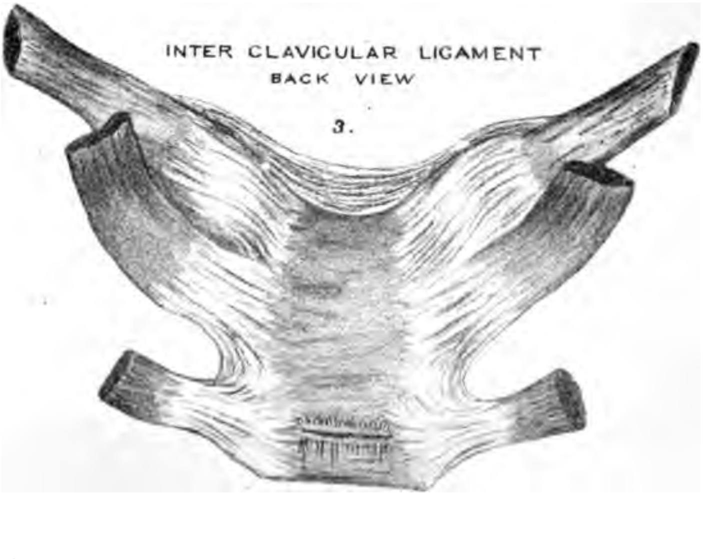
SECTION THROUGH STERNO CLAVICULAR JOINT


1.
Interarticular fibro cartilage
Synovial cavity of 2nd chondro-sternal joint

INTER CLAVICULAR LIGAMENT
FRONT VIEW
2.



INTER CLAVICULAR LIGAMENT
BACK VIEW
3.



Frank Steele del ad.nat. West Newman & C rially to bind the bones together, and to prevent more especially the inward and upward displacements of the clavicle from the sternum and costal cartilage. It also forms an elastic buffer or cushion between the bones, which tends much to break shocks; while at the same time, by its similarity in outline to the end of the clavicle and its adaptability to the socket of the sternum, it adds very much to the general security of the joint.

SYNOVIAL MEMBRANES.—There are two membranes in this articulation; for, owing to the peculiar attachment of the inter-articular ligament to the socket below and the clavicle above, as well as to the capsular ligament at its margins, there is formed a complete space or cavity between the fibro-cartilage and the sternum and costal cartilage on the inner side; and between the clavicle and the fibro-cartilage on the outer side. Thus one membrane is reflected over the outer side of the fibro-cartilage from the clavicle and capsule, and another over the inner side from the sternum, costal cartilage, and capsule. The former is more loose and sac-like than the latter. Occasionally a communication takes place between the two cavities.

Collectively the ligaments of this joint are very strong, and make up for the want of adaptation of the two bones. The joint indeed is stronger than the collar-bone, which is often fractured; whereas dislocation of the inner end of the clavicle is a very rare occurrence.

THE MOVEMENTS.—The movements permitted at this joint are various though limited, owing to the capsular ligament being moderately tense in every position of the clavicle. The joint is the centre at which many of the movements of the shoulder occur—such as the elevation of the arm over the head, and the forward and backward play of the arms, as in walking, running, swimming, rowing, and such like exercises. Motion therefore occurs at the sterno-clavicular joint in nearly every direction—upwards, downwards, backwards, forwards, and in a circumductory direction.

The upward and downward movements of the clavicle take place between that bone and the inter-articular fibro-cartilage. During elevation, the upper edge of the clavicle with its attached fibro-cartilage is pressed inwards into the sternal socket, and the lower edge of the clavicle is raised from the fibro-cartilage; during depression of the clavicle, the lower edge of the clavicle presses downwards and inwards upon the fibro-cartilage, and the rest of the articular surface inclines outwards, bringing with it to a slight degree the upper edge of the fibro-cartilage. These movements occur upon an axis drawn from before backwards through the outer compartment of the joint. The forward and backward movements occur between the fibro-cartilage and the sternal socket, the clavicle together with the inter-articular cartilage rolling backwards and forwards respectively upon the sternum; and the movements occur round an axis drawn nearly vertically through the sternal socket.

In circumduction, the movements are of course a compound of a quick succession of these four angular movements, and therefore take place partly between clavicle and fibro-cartilage, and partly between fibro-cartilage and sternum.

THE MUSCLES.—The muscles in immediate connexion with this joint are few in number, being only those which arise from the manubrium sterni, the inner end of the clavicle, and the costal cartilage of the first rib. These are the sterno-mastoid and the pectoralis major in front, the sterno-hyoid and sterno-thyroid behind, and the subclavius which is in front and to the outer side of the rhomboid ligament.

The sternal origin of the sterno-mastoid, which is tendinous, passes obliquely upwards and outwards (in the same direction as the anterior portion of the capsular ligament), over the front of the articulation, and strengthens very considerably the anterior sterno-clavicular portion of the capsule. This muscle affords a good illustration of the general law respecting the attachment of muscles to both bones of an articulation when they arise or are inserted in the near neighbourhood of a joint.

The sterno-hyoid muscle usually arises from the posterior ligamentous fibres of the joint, as well as from the clavicle, or the sternum. It gives security to the back of the joint.

The subclavius muscle may be considered as one of the uniting structures of the articulation, and like the costo-clavicular ligament it helps to prevent the too forcible or extreme elevation of the clavicle. It also assists the other ligaments in keeping the inner end of the clavicle in its place upon the sternum and costal cartilage—*i.e.*, in preventing avulsion of the clavicle from the sternum.

In addition to the above-named muscles, it must be remembered that the clavicle moves upon the sternal socket in every forward, backward, upward, and downward movement of the shoulder. So that all the muscles which move the shoulder act indirectly upon the sterno-clavicular joint; thus the trapezius and latissimus dorsi, the serratus magnus and pectoralis minor, the rhomboids and levator anguli scapulæ, will each and all influence this joint in accordance with their own actions, and in conformity with what is stated respecting the movements which occur at the sterno-clavicular articulation.

Indeed it is these muscles only which produce any of the ordinary movements at the sterno-clavicular joint; for none of the muscles in immediate relation with it act usually upon the clavicle, but have their *fixed* point at or near this articulation. Thus the sterno-hyoid, sterno-thyroid, and sterno-mastoid muscles, as well as the pectoralis major, act from, not upon, it; and, by the very nature of their connexion with it, do not tend to move one bone upon the other. The subclavius, however, by depressing the outer end of the clavicle causes the inner end to glide upwards and inwards upon the sternal socket, revolving round an antero-posterior axis, and thereby tightening the superior portion of the capsular ligament and the interclavicular ligament.

CHAPTER X.

THE LIGAMENTS AND JOINT CONNECTING THE SCAPULA WITH THE CLAVICLE; OR, THE SCAPULO-CLAVICULAR UNION.

THE scapula is connected with the clavicle by a synovial joint, which may be either divided or single, between the acromion process and the outer end of the clavicle; as well as by ligaments passing from the coracoid process to the under surface of the outer end of the clavicle. We have therefore to consider—1st. The acromio-clavicular articulation; and 2nd. The coraco-clavicular ligaments. It will also be most convenient and apposite to describe in this section the ligaments which pass from one part of the scapula to another—viz., the coraco-acromial, and the supra-scapular ligaments.

The Acromio-clavicular Joint.

Class, **Diarthrosis.** *Subdivision*, **Arthrodia.**

This joint is formed between the outer extremity of the clavicle and the inner edge of the acromion. Ligaments pass from one bone to the other on all their aspects, and there is frequently an inter-articular fibro-cartilage which sometimes is imperfect, and only partially separates the articular surfaces of the bones, but occasionally is complete, and divides the synovial cavity into two distinct parts.

THE CLAVICLE.—The outer end of the clavicle ascends towards the acromion in the male, so as to give height and squareness to the shoulders. It is flattened upon its superior and inferior surfaces, and has a narrow, convex posterior, and a narrow, concave anterior border. By its outer border, which is somewhat thicker than the anterior, but shallower than the posterior, it articulates with the anterior part of the internal edge of the acromion, and is marked by an oval-shaped, nearly flat facet for that purpose. The facet varies much in different bones, being sometimes large and irregular, and either slightly convex or concave; its long axis is in the antero-posterior direction, but the surface is somewhat oblique as it is sloped off inwards behind, and bevelled off slightly along its lower edge. This obliquity serves to explain the greater frequency of displacement of the outer end of the clavicle upwards upon, than downwards beneath, the acromion. The upper and under surfaces, as well as the anterior and posterior borders of the clavicle near the extremity, are rough, sometimes very rough and uneven, for the attachment of ligaments; and upon the upper surface there is often an oblique ridge running backwards and inwards to a little tubercle, or heaping-up of bone, at the posterior border, about midway between the conoid tubercle and the facet for the acromion. Its superior surface gives attachment to the trapezius behind, and the deltoid in front, for nearly equal distances. Its inferior surface is marked by a tubercle and ridge for the attachment of the coraco-clavicular ligaments.

THE SCAPULA.—It is by means of the acromion process alone that the scapula is brought into articular connexion with the clavicle. This process is a large and somewhat triangular prolongation of the spine of the scapula, about two inches in its longest, and rather over one inch in its broadest diameter. It has a general inclination upwards, so that in the undissected subject its extremity forms the highest part of the bone, and overhangs the glenoid fossa on its outer side. The elevation of the tip of the acromion above the rest of the scapula explains how it is that the clavicle in man has to ascend a little as it passes outwards from the top of the sternum, notwithstanding that the blade of the scapula does not reach higher than the second rib. It is directed at first outwards, and then forwards, twisting a little inwards, and has beneath it, and between it and the outer surface of the neck of the scapula, a large space leading from the supra- to the infraspinous fossa, and called the great scapular notch.

Its *upper surface* is rough and directly continuous with the outer or posterior border of the spine of the scapula; it looks chiefly upwards, but also outwards and backwards, and gives attachment along its outer edge to the deltoid, and along its inner edge to the trapezius. It is immediately beneath the skin, and forms the summit of the shoulder.

The *under surface* is smooth and slightly concave, and is directly continuous with the anterior or short border of the spine of the scapula; it looks chiefly downwards, but also slightly forwards and inwards, over the outer and upper part of the glenoid fossa.

Its *outer border* is convex and rough, and continuous with the lower lip of the outer border of the spine, and to it the deltoid is attached.

Its *inner border* is concave, thinner and much shorter than the outer; it is continuous with the upper lip of the outer border of the scapular spine, and has the trapezius attached along its posterior two-thirds.

At the anterior part of the inner border there is a nearly flat or slightly convex facet for the clavicle, which measures from a half to three-quarters of an inch in the antero-posterior, and a quarter of an inch in the vertical direction; it is sloped slightly outwards behind, and bevelled off along the upper edge, its obliquity being the reverse of that of the facet on the clavicle, which slopes inwards behind and is bevelled off below.

The *apex* of the acromion is the thin and somewhat pointed anterior edge between the facet for the clavicle and the outer border of the process. It projects an inch further forwards than the glenoid fossa, and overhangs the middle of the head of the humerus, when the arm is hanging loosely by the side.

The acromion process and clavicle together form an arch over the front and outer part of the thorax. This arch has one fixed pier, viz., the sternum; and one movable pier, viz., the spine and body of the scapula. The arch is connected with the fixed pier by an articulation at which all the movements of the whole arch take place; but is structurally continuous with the movable pier, which therefore moves together with the arch. The vault of the arch itself is jointed, so that the outer and shorter limb can move upon the inner and longer, viz., at the acromio-clavicular joint.

Beneath the arch thus formed important structures pass. The coracoid process projects upwards and forwards, so as to divide the subway into two portions, the larger being on the inner or thoracic side of the process. In the thoracic portion, that is, under the clavicular part of the arch, lies the subclavius muscle, and the axillary vessels, respiratory nerve of Bell, and cords of the brachial plexus descend through it into the upper arm.

In the acromial portion of the subway there are the supra-scapular nerve and artery, passing to the great scapular notch; the supra-spinatus, passing forwards to the great tuberosity of the humerus; the sub-acromion bursa, which protects the capsule from the deltoid, and the shoulder-joint itself, which is overhung by the acromion process.

LIGAMENTS.—There is one ligament, and occasionally an inter-articular fibro-cartilage, concerned in the construction of the acromio-clavicular joint.

The *capsular ligament* completely surrounds the articular margins, and is composed of coarse strong fibres, having an uniform and definite direction, which are attached to the anterior and posterior borders, as well as to the upper and under surfaces of the acromion and clavicle. The ligament is somewhat lax in nearly every position of the joint, so that the clavicle is by no means tightly braced to the acromion, but is retained somewhat loosely in apposition with it. The fibres reach a variable distance upon the different aspects of the bones; thus posteriorly, they extend inwards for three-quarters of an inch or more upon the clavicle, as far as a little tubercle external to the one for the conoid ligament; superiorly, they are attached to the oblique line which runs outwards and forwards upon the upper surface of the clavicle, and thus they extend a shorter distance upon the bone as they reach nearer and nearer the anterior border. At the anterior border they do not extend more than a quarter of an inch along the clavicle; and inferiorly, they reach outwards to the ridge for the trapezoid ligament, with the fibres of which they blend. At the acromion the fibres of the ligament reach about half-way outwards upon both the upper and lower surface, while along the borders of the process they are very short, being attached immediately in front of, and behind the articular facet. The anterior, and a few of the antero-inferior fibres are blended at their insertion into the apex of the acromion with the coraco-acromial ligament.

The capsule is of pretty uniform thickness, but is strengthened above by the aponeuroses of the trapezius and deltoid muscles; it is about as thick as a shilling, and its fibres are arranged in coarse and parallel fasciculi. These fibres all run inwards and backwards from the acromion to the clavicle, and the posterior fibres extend much further inwards upon the convex border and upon the posterior part of the upper and lower surfaces of the clavicle than elsewhere. This definite direction and varied length of the fibres serve the purpose of dragging the clavicle forwards when the acromion is advanced; while the anterior part of the capsule, and the projection of the apex of the acromion in front of the extremity of the clavicle, secure the backward movement of the latter when the scapula is pulled towards the dorsal spines.

Were it not for the bevelling of the facets, already referred to, the laxity of the ligament would permit of a slight dropping of the clavicle from the acromion; as it is, the clavicle somewhat overlaps so as to rest upon the acromion. This overlapping of the clavicle, which in some instances is so marked as to cause quite an elevation, tends also to prevent any upward displacement of the acromion by the pressure of the head of the humerus, during such muscular efforts as pushing or bearing the weight of the trunk upon the palms of the hands.

The Inter-articular Fibro-cartilage.—A fibro-cartilage is occasionally present; when it is so it is usually imperfect, and extends only half-way through the joint from above downwards. Sometimes it reaches the whole depth and is perforated in the centre. It is usually thicker at the circumference than towards the interior, and some of the fibres of the capsular ligament are blended with its edges.

THE SYNOVIAL MEMBRANE.—A synovial membrane lines the joint, and when the inter-articular cartilage is present the cavity it forms is either partly or completely divided according to the state of the cartilage upon which the membrane is reflected.

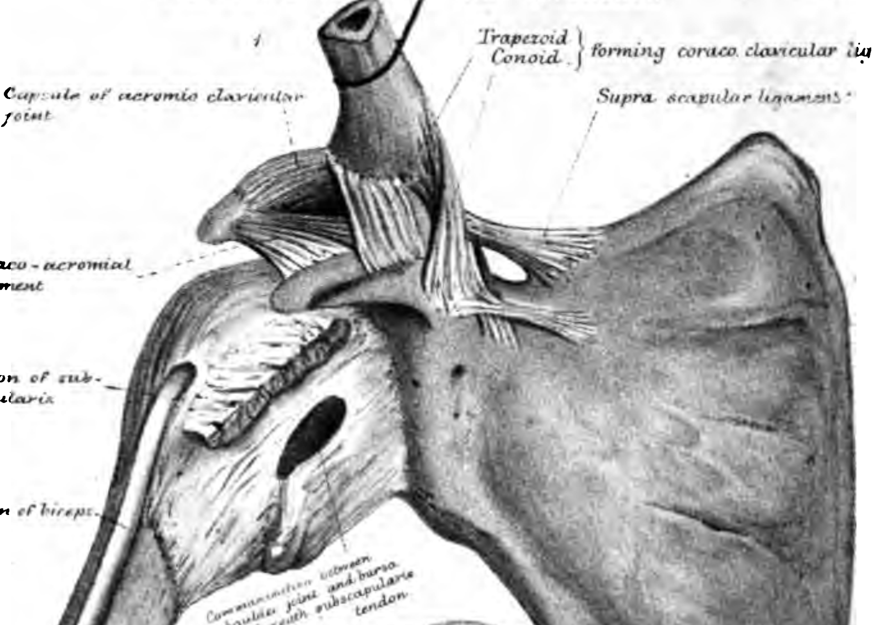
The Coraco-clavicular Union.

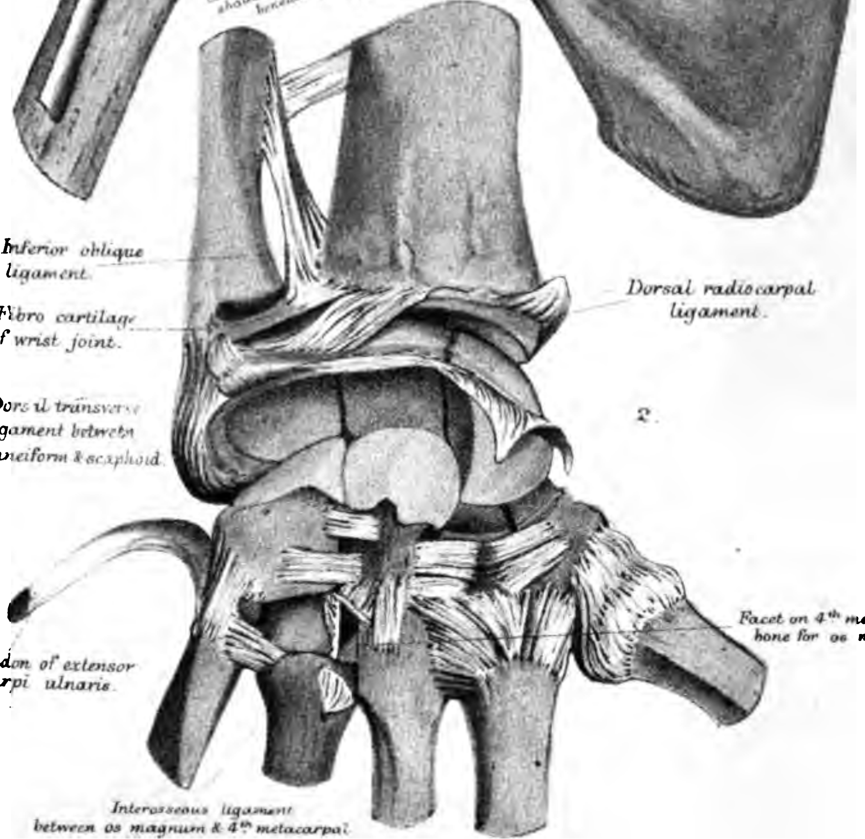
CORACOID PROCESS.—The coracoid or hook-like process overhanging the upper border of the glenoid fossa on its inner side, to the very margin of which it often extends, is situated beneath the acromio-clavicular arch, the subway of which it divides into two unequal parts. It springs by a broad thick base an inch wide, from the upper costa of the scapula between the supra-scapular notch, one margin of which it forms, and the edge of the glenoid fossa. It may indeed be said to contribute to the formation of the fossa, and with it is situated in advance of the surgical neck of the scapula. It affords powerful leverage to the coraco-brachialis and biceps muscles which are attached to the outer edge near the apex; and it is marked on its inner border near the apex by a smooth facet into which the pectoralis minor is inserted. Its surfaces look upwards and outwards, and downwards and inwards, and serve to separate the great scapular notch from the sub-scapular fossa. Having ascended, with a considerable leaning over the sub-scapular fossa, for about half an inch, the process suddenly becomes contracted to a quarter of an inch in width. It is twisted on itself so that its surfaces now look upwards and inwards, and downwards and outwards over the glenoid fossa; and its direction is changed so that it projects forwards for three-quarters of an inch beyond the edge of the glenoid fossa. Its apex, its narrowest point, is bent very slightly downwards. It thus, as its name implies, somewhat resembles the beak of a raven. It is situated an inch and a half to the thoracic side of, and half an inch below, the level of the acromion, and is on a level with the upper surface of the head of the humerus. The centre point of the outer curve of the clavicle is situated in a vertical line immediately above the angle of the coracoid at a distance of about half an inch. Extending forwards from the angle where the ascending suddenly changes into the horizontal part, the bone is raised into a rough and oblique ridge, which separates the outer surface of the vertical from the upper surface of the horizontal portion of the process, and is prolonged upon the outer edge to the apex. This ridge gives attachment to the coraco-acromial ligament. The inner edge is marked by a rough ridge which extends forwards for an inch or more, and gives attachment to the trapezoid portion of the coraco-clavicular ligament. On the inner side of the angle of the coracoid is a smooth and sometimes facetted surface, against which plays the conoid ligament in the backward and forward movement of the scapula.

The coraco-clavicular ligament consists of two parts—the conoid and the trapezoid.

The *conoid ligament* is the most internal as well as the posterior portion. It is a very strong and coarsely fasciculated band of triangular shape, extending upwards and outwards from the inner side of the root of the coracoid, to the tubercle on the under surface, and posterior edge of the outer curve of the clavicle. Its apex is at the inner and posterior edge of the

LIGAMENTS ABOUT THE SHOULDER. PLATE X

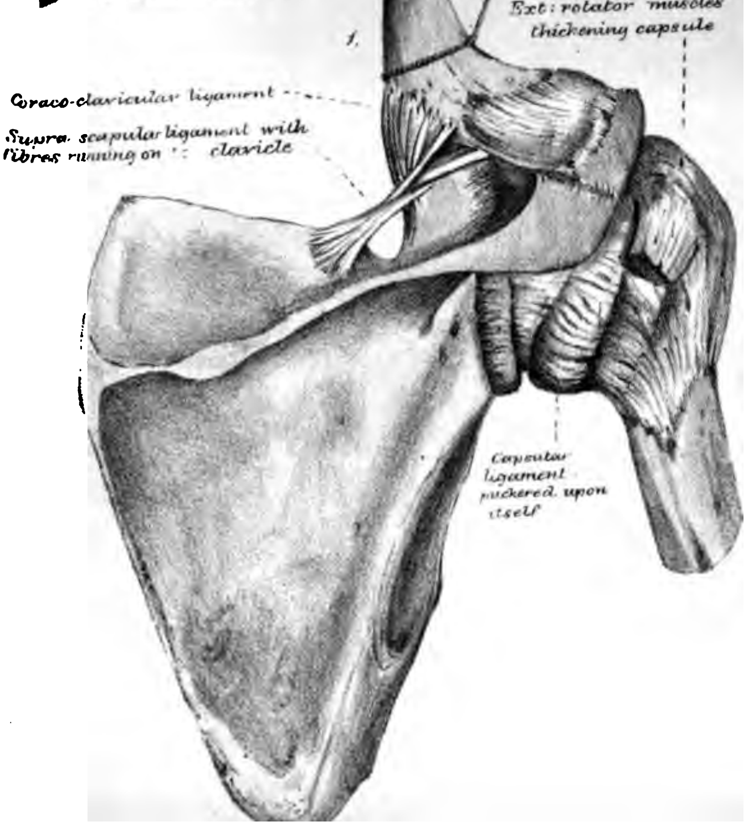

1
Capsule of acromio clavicular joint
Trapezoid
Conoid } forming coraco clavicular lig
Supra scapular ligament
Coraco-acromial ligament
Tendon of subscapularis
Tendon of biceps
Communication between shoulder joint and bursa beneath subscapularis tendon


Inferior oblique ligament
Fibro cartilage of wrist joint
Dorsal transverse ligament between cuneiform & scaphoid
Dorsal radio carpal ligament
2.
Facet on 4th metac
bone for os mag
Tendon of extensor carpi ulnaris
Interosseous ligament between os magnum & 4th metacarpal bone shutting off general synovial cavity from that between unciform & 4th & 5th metacarpal bones.

West Newman & Co. chr. lith.

INTERCARPAL JOINT LAID OPEN FROM THE DORSUM.

VIEW OF CAPSULAR LIGAMENT
THE SHOULDER JOINT


1.
Ext: rotator muscles thickening capsule
Coraco-clavicular ligament
Supra. scapular ligament with fibres running on ·: clavicle
Capsular ligament puckered upon itself

LIGMENTS OF WRIST
AS SEEN FROM THE PALMAR ASPECT

2.

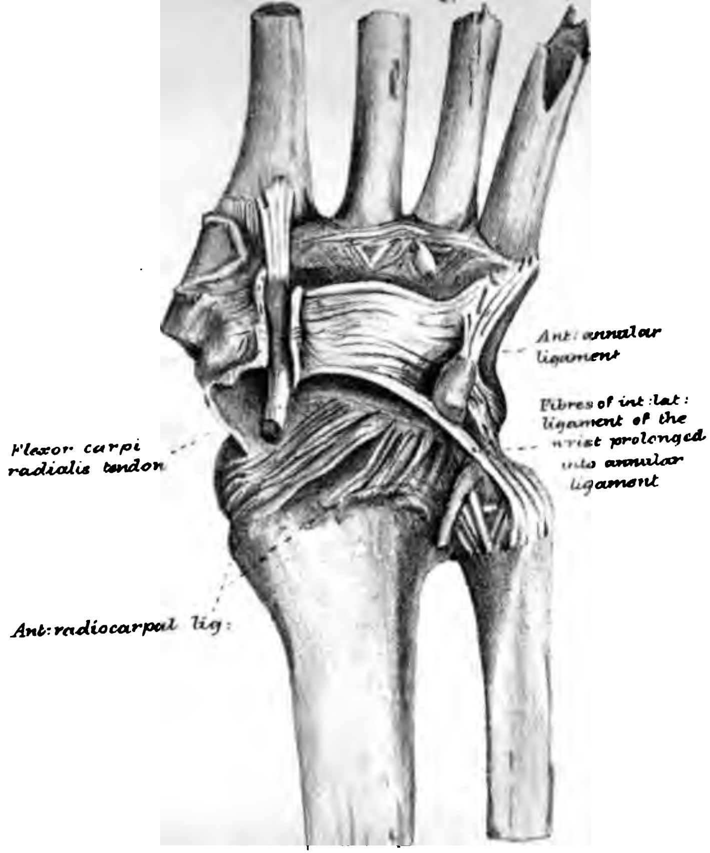

Ant: annular ligament
Fibres of int: lat: ligament of the wrist prolonged into annular ligament
Flexor carpi radialis tendon
Ant: radiocarpal lig:

PLATE XVIII.

root of the coracoid process and immediately in front of the supra-scapular notch; some of its fibres are connected with the scapula even below the supra-scapular notch, and reach into the venter for some short distance. Others pass backwards over the supra-scapular notch and form part of the transverse ligament. Its base is at the clavicle, where it widens out laterally so as to be attached to the posterior edge of the lower surface of the clavicle, on the outer side of, as well as into the tubercle above mentioned. The ligament is somewhat twisted on its own axis as it ascends, so that the anterior fibres at the coracoid become internal at the clavicle, and are inserted into that bone at and near to the tubercle, while the fibres which are posterior at the coracoid, pass outwards upon the clavicle and are prolonged from the inner and upper edge of the supra-scapular ligament to the posterior edge of the trapezoid ligament. Without being absolutely distinct it is easily separated from the trapezoid ligament, both at the coracoid and the clavicle. It works backwards and forwards on the facet on the inner aspect of the angle of the coracoid, between which and the ligament there is often a distinct bursa.

The conoid ligament chiefly checks the backward movements of the scapula as the trapezoid does the forward movements of that bone. It therefore protects the scapula against backward displacement, either from the action of the posterior muscles, such as the rhomboids and part of the trapezius, or by blows on the front of the shoulder. The coraco-clavicular ligament as a whole limits the movements of the acromio-clavicular joint, just as the costo-clavicular does those of the sterno-clavicular joint.

The *trapezoid ligament* is the anterior and outer portion of the coraco-clavicular. It is a strong flat plane of closely woven fibres, the surfaces of which look respectively upwards and inwards towards the clavicle, and downwards and outwards over the upper surface of the coracoid process, and the glenoid fossa. It is more oblique in direction than the conoid, which is nearly vertical. It is quadrilateral in shape, with its anterior edge longer than the posterior, and its upper surface sloped off obliquely behind. At the coracoid it is attached for about an inch to the rough ridge which runs forwards from the angle along the inner edge of the process, as well as to the angle itself immediately above the facet for the play of the conoid ligament; some of its fibres are placed under cover of the conoid ligament. At the clavicle it has rather a more lengthy attachment to the oblique ridge which runs outwards and forwards from the tubercle for the conoid on the under surface of the bone. Its posterior edge is in juxtaposition to the outer and hinder portion of the conoid ligament, while its anterior border is free in the dissected state, and overlies the base of the coraco-acromial ligament. At the extremity of the clavicle it blends with the inferior part of the acromio-clavicular capsule.

The trapezoid ligament chiefly limits the forward movements of the scapula, as the conoid does the backward movements of that bone. Like the conoid, it strengthens very materially the acromio-clavicular joint, preventing the scapula from being displaced inwards beneath the clavicle either by violence or muscular action—a tendency to which the obliquely cut surfaces of the clavicle and acromion dispose the joint.

THE MOVEMENTS BETWEEN THE SCAPULA AND CLAVICLE.—Owing to the want of security afforded by the shape of the articular surfaces of the acromion, and outer end of the clavicle, the entire strength of the acromio-clavicular joint must be derived from ligaments. These ligaments, while knitting the bones together with sufficient firmness to enable them to resist all ordinary displacing forces, do not permit of more than very limited movements taking place between them. To understand what these movements are, we must bear in mind that it is the scapula which moves upon the outer end of the clavicle, although the clavicle in its turn, carried by the ligaments which unite it with the scapula, moves upon the sternum. But the scapula, in moving upon the end of the clavicle, moves likewise upon the thorax in a forward and backward, as well as in an upward and downward direction, and also in a rotatory manner around a line, drawn at right angles to the flattened blade, below the spine of the scapula. Throughout these movements the lower angle and the base of the scapula are kept in contact with the ribs by the latissimus dorsi, which straps down the former, and by the serratus magnus and rhomboids attached to the latter. This being the case, had there been no acromio-clavicular joint, as the scapula glided forwards and backwards on the thorax, the glenoid socket could not have preserved its obliquely forward direction; on the contrary, the socket would have shifted round a vertical axis, and the shoulder would have pointed inwards when the scapula was advanced, and outwards when it was drawn backwards towards the spine, to a degree greater than would be desirable or convenient. This disadvantage would have been especially felt in striking forwards from the shoulder; for at the same time that the arm was outstretched, the scapula rolling forwards round the thorax, and having its centre of motion at the sterno-clavicular joint, would, if immovably fixed to the outer end of the clavicle, have had the direction of the glenoid fossa so diverted inwards that it would no longer have afforded a surface fairly opposed to the head of the humerus, but would have presented an inclined surface, off which the head of the humerus would have had a tendency to glide, and thus to force its way through the inner and forepart of the capsule of the shoulder-joint.

By means of the acromio-clavicular joint the scapula can be forcibly advanced upon the thorax and yet keep its glenoid socket facing fairly forwards, the scapula so moving upon the clavicle as to make the posterior angle between the clavicle and acromion process more acute. In this way the force of the muscles of the shoulder, arm, and forearm can be combined in giving a direct blow; while at the same time the shock received by the fist, and passing through the length of the humerus, is transmitted directly from the head of that bone to the glenoid cavity, and is thence distributed to the anterior costa and the superior costa through the base of the coracoid process, and indirectly transmitted through the acromion and along the spine of the scapula to the posterior costa of the scapula, and forwards to the clavicle, and along it to the sterno-clavicular joint. It is well known that the most forcible blow that can be delivered is when the side of the body is inclined towards the object to be struck, and the arm is thrown outwards and forwards from that side. This is the movement of boxing, and the attitude and movement of fencing. With the scapula well drawn back towards the spine, the posterior angle formed by the acromion and clavicle at its most obtuse degree, and the shoulder and elbow joints bent, the muscles which draw the scapula away from the spine are ready to act simultaneously with those which straighten the shoulder and elbow; during their action the glenoid socket is kept fully against the head of the humerus, and the clavicle and acromion are brought to their most acute angle at the acromio-clavicular joint.

It must be borne in mind that whilst the base of the scapula is held against the thorax and revolves upon it, yet that the entire scapula moves in the arc of a circle, whose centre is the sterno-clavicular joint, and whose radius is the clavicle; and not in the arc of the circle formed by any one of the five costal arches upon which it is placed, each one of which, moreover, differs from the rest. Now as this radius is elastic; as part of the venter of the scapula has to be retained in contact with the thoracic wall; and as owing to the pull of the various muscles which act on the scapula there is a considerable tendency to drag the scapula inwards in such a manner that it would, if possible, get nearer the centre of the circle the further towards the front it came; the radius, instead of remaining straight, would gradually become curved backwards near its junction with the arc, while a counter, forward, curve would be formed at the opposite end. This, too, would occur notwithstanding the movements of the acromio-clavicular joint. Thus it seems to me that the curves of the clavicle are to be explained by the shape of the thorax, against which the scapula is held by muscles, and by the direction of the pull of those muscles as they drag forwards the scapula upon the outer extremity of the radius formed by the clavicle. Hence, too, we see more considerably curved clavicles in males than in females, and in muscular men than in the weakly or inactive.

Again, were it not for the acromio-clavicular joint, the lower angle of the scapula could not have been retained in contact with the chest wall during the rising and falling of the shoulder, owing to the increase in the diameter of the chest from the second to the seventh ribs; while the glenoid fossa would have shifted round a transverse axis, so that its upper end would be tilted downwards when the body of the scapula was raised, and thrown upwards when the scapula was depressed.

When moving forwards and backwards the scapula turns round a vertical axis drawn through the acromio-clavicular joint, in a hinge-like manner upon the end of the clavicle, carrying with it at the same time the outer end of the clavicle itself, so that both advance and retire together; and the inner end of the clavicle moves upon the fibro-cartilage of the sterno-clavicular joint. When the scapula ascends and descends, it turns in a hinge-like manner round a transverse axis drawn through the joint, upon the extremity of the clavicle, while at the same time the clavicle together with the fibro-cartilage of the sterno-clavicular joint moves upon the costo-sternal socket.

In the rotation of the scapula, round an axis through its own centre, and at right angles to its flat surfaces, the acromion moves in a complex manner upon the clavicle round both the vertical and transverse axes. Such rotation occurs when we raise, and at the same time advance, the shoulder, as when we reach anything above our head, or take off our hat; and when we depress and at the same time draw back the shoulder.

There are no movements in which the clavicle moves upon the acromion while the scapula is fixed, nor in which the scapula moves on the fixed clavicle. They mutually affect each other, so that the muscles which act upon the one move both bones.

THE MUSCLES MOVING THE SCAPULA AND THE CLAVICLE.—From what has been said above, it will be understood that the scapula and clavicle together move in the arc of a circle, the radius of which is the clavicle, and the centre the sterno-clavicular joint; that while the posterior costa and inferior angle of the scapula are retained by muscles against the chest wall, the rest of the scapula is thrown off from the side and front of the thorax, as it advances or rises, by its connexion with the clavicle, *i.e.*, with the radius of the circle in which it moves; but that this connexion is a movable and not a fixed one, in order that while moving together the bones may also move on one another, for the purpose of giving uniformity to the direction of the glenoid socket, joints, and the shoulder.

The acromio-clavicular joint being a hinge joint, in which neither part of the hinge is fixed, any muscle which tends to move one portion in any direction will similarly affect the other, and will at the same time move the two bones upon the sterno-clavicular joint.

The muscles may be grouped into those which act *directly*, and those which act only occasionally and indirectly upon the joint. 1. Most of the muscles which act directly upon it are inserted into the scapula alone. They are the *levator anguli scapulæ*, inserted into the upper angle of the posterior costa; and the *rhomboids*, attached to the posterior costa, all of which pull the bone back towards the spine, and help to keep the base of the scapula against the chest wall. The levator also elevates the scapula and rotates it so as to depress the glenoid fossa. The *serratus magnus*, inserted into the whole length of the base as well as the upper and lower angles on the ventral surface, draws the scapula forwards and keeps the base and upper and lower angles against the chest wall; the *pectoralis minor* inserted into the inner side of the tip of the coracoid process pulls the anterior angle of the scapula downwards and forwards, and thus tends to throw the inferior angle backwards.

2. One important muscle, acting directly upon the joint, is inserted into both clavicle and scapula—viz., the *trapezius*. The superior fibres of the trapezius elevate the outer half of the clavicle, the middle fibres elevate the acromion, and the inferior fibres draw the spine of the scapula downwards and towards the spinal column. When all the fibres of the muscles act together the scapula is rotated, so that the acromion is raised and drawn inwards towards the column, the superior angle is depressed and drawn inwards, and the inferior angle is thrown away from the spinal column and elevated.

3. One muscle, acting on the joint, is inserted into the clavicle alone—viz., the *subclavius*. Attached to the groove on the under surface of the bone, as far outwards as the recess between the conoid and trapezoid ligaments, it depresses the outer end of the clavicle. All the muscles, excepting the subclavius and the superior fibres of the trapezius, act first on the scapula, which then carries with it the clavicle, whereas these two muscles act first on the clavicle, which then carries with it the scapula.

It should be noticed that the subclavius extends obliquely the whole way between the costo-clavicular and coraco-clavicular ligaments, and by assisting these ligaments to keep the clavicle in its proper position it must give support and security to both the sterno- and the acromio-clavicular joints; to the former by holding the inner end of the clavicle inwards against the chondro-sternal facet; and to the acromio-clavicular by preventing the upward and outward displacement of the outer end of the clavicle upon the acromion.

If the actions of the several muscles be considered collectively, the trapezius, levator anguli scapulæ, and the rhomboids elevate the scapula and outer part of the clavicle; the lower part of the trapezius, the pectoralis minor, and the subclavius depress them. The serratus magnus carries them forwards, and the trapezius and rhomboids draw them backwards. By the associated action of these muscles rotation is produced.

The muscles which act indirectly upon the bones of the shoulder act from the humerus and forearm when these parts are fixed. They are (1) the latissimus dorsi, which arises by a few fibres from the inferior angle of the scapula, and by passing over it like a strap assists the lower part of the serratus magnus in keeping it against the thorax, and limits its outward projection when the arm is raised. The latissimus dorsi and pectoralis major act powerfully upon the shoulder when they have brought the arm into contact with the side, or when the deltoid has fixed the shoulder-joint; thus the pectoralis major draws forwards and downwards the shoulder when we cringe with cold or fear; and the latissimus dorsi, with arms against the sides, throws the shoulders downwards and backwards at the order "attention." (2) The deltoid, biceps, coraco-brachialis, and triceps depress the shoulder when the arm is fixed in a downward position. (3) The supra- and infra-spinatus, the teres major and minor, and sub-scapularis draw it forwards. But all these muscles are concerned primarily in moving the humerus at the shoulder-joint, and only under exceptional conditions move the shoulder bones upon the sterno-clavicular joint, or on one another at the acromio-clavicular articulation.

BURSÆ.—There are usually three bursæ in association with this joint and its ligaments. 1. In the recess between the conoid and trapezoid ligaments. 2. Between the base of the coracoid process on its inner side, and the apex of the conoid ligament. 3. Below the coraco-acromial ligament, between it and the acromion above, and the capsule of the shoulder-joint below. This last is usually of considerable size, the other two are but very small sacs.

ARTERIES.—The *supra-scapular* artery gives off behind the clavicle a branch which supplies the subclavius muscle, and extends along it as far as the conoid and trapezoid ligaments. These ligaments are pierced by twigs from this branch, which afterwards get into the joint on the inferior aspect.

Another branch is given off from the supra-scapular artery, which curves round the lower edge of the supra-spinatus, reaches the under aspect of the acromion and acromio-clavicular joint, and supplies it. There is quite a free anastomosis of small arteries on the under surface of this joint, and the coraco-clavicular ligaments are also supplied from the same source.

The acromial branch of the *acromio-thoracic axis*, the *anterior circumflex*, the *supra-scapular*, and sometimes a branch from the *transversalis colli*, anastomose upon and supply the joint by piercing it on the upper surface.

NERVES.—Branches are sent to this joint from the supra-scapular and the circumflex.

Scapular Ligaments.

There are two ligaments proper to the scapula—that is, passing from one point to another of the bone, and not connected with any other bone. These are the coraco-acromial, and the transverse or supra-scapular ligaments.

The *coraco-acromial ligament* is a broad, triangular, flat membrane, wide at the coracoid and contracted to a blunt apex at the acromion process. It is composed of strong fibres, which are attached all along the outer edge of the horizontal portion of the coracoid, and after passing with varying degrees of obliquity outwards and a little upwards, they are inserted into the apex of the acromion, as well as into the process immediately below the facet for the clavicle, close to the inferior fibres of the acromio-clavicular capsule.

The fibres which arise most posteriorly from the coracoid are the thickest, and run forwards slightly, as well as outwards and upwards, to their insertion. Some few of them overlap the rest, and get inserted into the apex of the acromion.

The fibres which arise most anteriorly from the coracoid are also strong, and most of them are inserted into the apex of the acromion, but a few pass beneath the rest to be attached below the facet for the clavicle.

The intermediate fibres are thinner and more membranous, and are inserted at the acromion beneath the anterior and posterior fibres. The surfaces of this ligament look—the one, upwards and slightly forwards, the other, downwards with a slight inclination backwards. It overhangs the shoulder-joint, from the capsule of which it is separated by a bursa, and the tendon of the sub-scapularis muscle. The posterior edge is in the same vertical plane as the anterior border of the outer end of the clavicle. The anterior edge projects over the centre of the head of the humerus. The ligament measures more than an inch and a quarter from before backwards at the coracoid, but less than half an inch at the acromion. It is barely one-third of an inch above the capsule of the shoulder-joint, and in the undissected subject, especially near the glenoid cavity, there is not a quarter of an inch interval.

It serves to bind the coracoid and acromion processes together, and to strengthen each by their union, enabling the acromion to resist forces which tend to drive it outwards, and the coracoid forces which would displace it inwards. It likewise holds off the deltoid muscle from the capsule of the shoulder, and protects the joint from violence directed downwards and backwards upon it. In some animals, such as the sloths, the two processes are still further strengthened by a bony arch.

The *transverse, coracoid, or supra-scapular ligament* is a small triangular band of fibrous tissue, having its surfaces looking inwards and outwards, and its edges, which are thin and sharp, turned upwards and downwards.

It forms a continuation of the superior costa, which it connects with the angle of the coracoid process, while it bridges over the supra-scapular notch. Its base is behind, where it springs from the upper border, especially on its external aspect, of the scapula, for a distance of one-third of an inch behind the notch. Its apex is at the outer lip of the angle of the coracoid process, where its fibres are inserted under the edge of the trapezoid ligament; but some of its internal and upper fibres are continued directly onwards into the outer edge of the conoid ligament, with the fibres of which they are inserted into the clavicle. The posterior edge of the trapezoid ligament is thus embraced by or interdigitated between fibres of the supra-scapular ligament. It serves to bridge over the supra-scapular notch, and to make the superior costa of the scapula directly continuous with the coracoid process.

CHAPTER XI.

THE SHOULDER-JOINT.

Class, Diarthrosis. *Subdivision*, Enarthrodia.

THE shoulder is one of the most perfect and beautiful, and at the same time the most movable of joints.

Like the hip, it is an *enarthrodial*, or ball and socket joint, and consists of a large ball—viz., the head of the humerus, playing in a shallow cup—viz., the glenoid fossa of the scapula. It is retained in position much less by ligaments than by muscles and the effect of atmospheric pressure; and from the looseness of its capsule, as well as from all the other conditions of its construction and position, it is exceedingly liable to be displaced. As against its exposed position it has this defence, that it is sheltered beneath large projecting processes—the acromion and coracoid.

THE SCAPULA.—The portion of the scapula which enters into the formation of this joint is the most important segment of the bone, and to its functions the general shape and disposition of the rest are adapted. It is usually described under the name of *external* or *articular angle* of the scapula, but may more appropriately be styled the *glenoid process*. This process presents an articular depression—the glenoid cavity; by its body it supports the coracoid process, while it is marked off from the expanded ala of the scapula by a constriction immediately behind the root of the coracoid process, named the *surgical neck of the scapula*. It forms the anterior or external angle of the scapula.

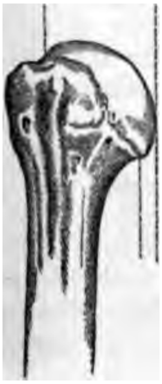
The *glenoid cavity* is a very shallow articular depression, situated on the free surface of the glenoid process. It is of an oval shape, with its long diameter vertical, or nearly so, and measures usually about an inch and a half; it is wider below than above, being usually an inch from side to side at its widest part, and gradually narrowing towards the upper end, it is there less than three-eighths of an inch. The curve of the outer margin is uniform, but that of the inner is slightly notched or indented near the apex, so that the general outline of the cavity presents the appearance of a section through a somewhat irregularly shaped pear. Its general direction is outwards, forwards, and a little downwards. It is coated in the recent state by articular cartilage, which is thinnest at the centre, and gradually thickens towards the circumference. To the margins is attached the glenoid ligament—a fibro-cartilaginous structure, by which the cavity is deepened; and to the rough surface beyond the margin—*the neck of the glenoid process*, or as it is sometimes described, the anatomical neck of the scapula—the capsular ligament of the shoulder is connected. The margin of the cavity is a little more prominent on the inner side than on the outer, and in this direction a greater liability to displacement lies; but the thickest and strongest part of the margin, as well as the broadest part of the cavity, is below. It is this lower part which sustains the chief pressure of the head of the humerus both from muscular action and violence, and on this account it is strengthened by the thick curved anterior costa of the scapula, as well as by a thick ridge running downwards from the margin of the cavity along the costa.

The base of the coracoid process forms the upper edge of the glenoid cavity, and, together with the glenoid process, is situated beyond the *neck of the scapula*—usually described as the surgical neck of the scapula. The great scapular notch, which leads from the supra- to the infra-spinous fossa, is on the outer part of the neck of the scapula, or, in other words, of the glenoid process, between the spine and glenoid cavity.

THE HUMERUS.—The superior extremity of the humerus consists of a globular *head* and two non-articular eminences—called the greater and lesser tuberosities.

The head forms part of a true sphere, and in the recent state is covered with articular cartilage which is thickest over the middle. The smooth articular surface of the head is limited by a sinuous irregular margin forming by no means a true circle, and is received into the glenoid cavity of the scapula. It looks upwards, inwards, and a little backwards, being set off obliquely from the inner and back aspect of the extremity of the shaft. Below the sinuous margin is a slight and narrow constriction, best marked in the upper half of its circumference and gradually merging off into the shaft below; it separates the head from the shaft and tuberosities, and is styled *the anatomical neck of the humerus.* It forms a contrast to the elongated neck of the femur which carries off the head of that bone to some distance from the shaft. This neck is perforated in its lower half by several large foramina for bloodvessels, and gives attachment all around to the capsular ligament of the shoulder.

DIAGRAM III.



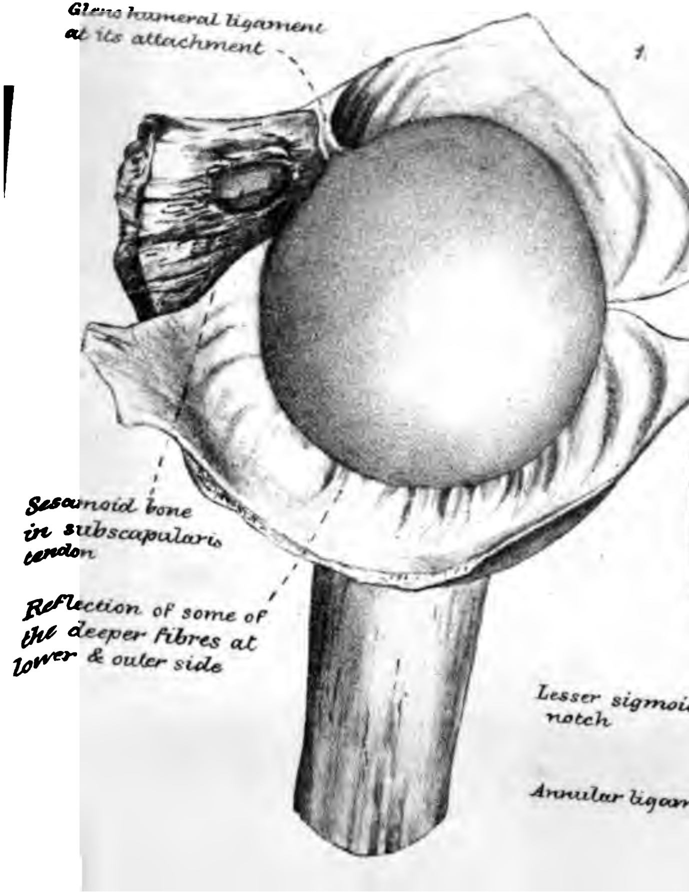
The greatest measurement of the articular facet is in a horizontal direction on a line with the base of the greater tuberosity and the middle of the lesser; this measurement is usually about two and a half inches; the next greatest is in a vertical direction from the ridge on the greater tuberosity separating the facet for the supra- from that for the infra-spinatus muscle, to the under side of the anatomical neck; this is usually about one-eighth of an inch less than the foregoing. It will be seen on looking at the accompanying diagram how much more of the articular surface is above than below the horizontal axis of the head.

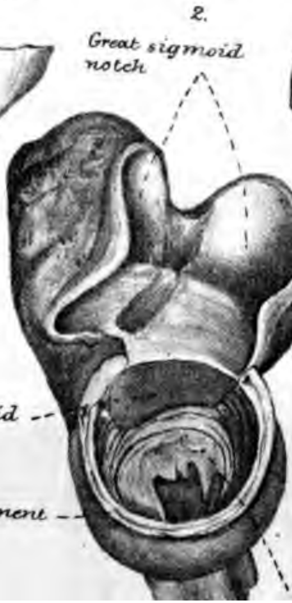
The *greater tuberosity* surmounts the outer side of the shaft of the bone, and extends obliquely around to the posterior aspect. It is separated from the globular articular surface of the head by the narrow constriction forming the anatomical neck, and from the lesser tuberosity by the deep groove for the biceps tendon. Its upper surface is marked by three flattened smooth facets separated by two narrow slight ridges which mark the insertion of the supra- and infra-spinatus and teres minor muscles. Its outer surface is rough and continuous with the shaft of the humerus.

The *lesser tuberosity* surmounts the anterior aspect of the shaft, and is more prominent, though smaller, than the greater. It slopes obliquely downwards and inwards from the inner margin of the bicipital groove, and like the greater tuberosity is most prominent where it forms part of the boundary of that groove. It is separated from the articular surface of the head by the anatomical neck, and on its summit is a facet for the insertion of the tendon of the sub-scapularis.

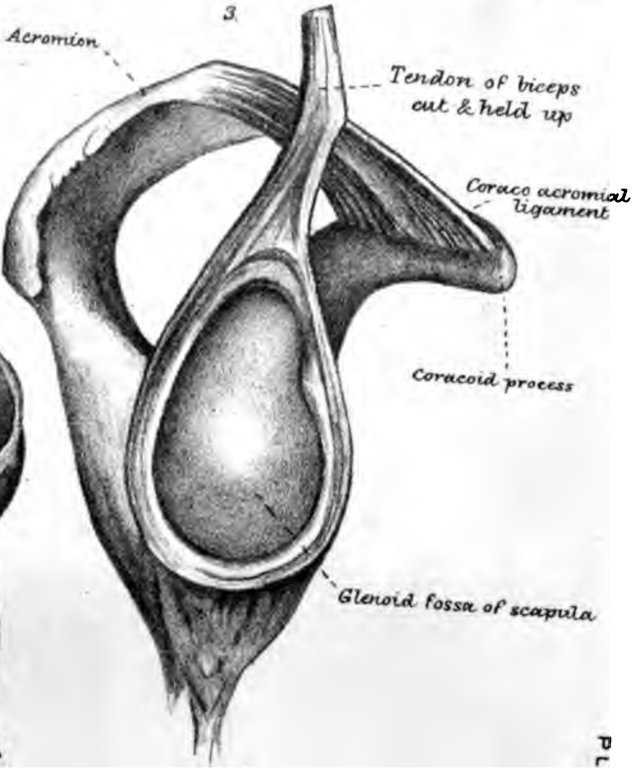
The bicipital groove is deep and narrow above, where it is

HEAD OF HUMERUS WITH CAPSULE OF SHOULDER ATTACHED


1.
Gleno humeral ligament at its attachment
Sesamoid bone in subscapularis tendon
Reflection of some of the deeper fibres at lower & outer side



THE GLENOID LIGAMENT THICKENED BY THE FIBRES OF THE BICEPS TENDON WHICH BIFURCATES & PASSES ON EACH SIDE



bounded by the tuberosities, and is lined by a thin layer of articular cartilage and a prolongation of the synovial capsule of the shoulder-joint; it is shallow, and a little broader below, where it inclines downwards and inwards on the front of the shaft. It commences at the anatomical neck between the external and internal tuberosities, and ends on the lower part of the upper third of the shaft.

Below the tuberosities the bone becomes rapidly smaller as the superior extremity passes into the shaft. This part of the bone is called the surgical neck of the humerus, but it has no special importance in relation to the shoulder-joint.

THE LIGAMENTS.—The ligaments of the shoulder-joint consist of a capsule, and a ligament superadded to the capsule at one part—viz., the coraco-humeral. There is also a circumferential fibro-cartilage, called the glenoid ligament. Moreover, the tendon of the biceps, which arises from the glenoid process of the scapula and passes over the head of the humerus, must be considered with the ligaments of the joint.

The *capsular ligament* is a loose sac insufficient by itself to maintain the bones in contact. It consists of fairly distinct, but not coarse fibres, closely woven together and running, some straight, others obliquely, between scapula and humerus; and of others again interwoven with the foregoing and passing circularly amongst them.

At the scapula it is fixed, all around the dorsal aspect, to the prominent rough surface of the glenoid process, and even extends beyond, to be attached to the outer part of the great scapular notch. Above, it is fixed to the root of the coracoid. On the inner side it is attached to the ventral surface of the glenoid process at a variable distance from the articular margin, occasionally reaching upwards to the under surface of the horizontal arm of the coracoid, and often for half an inch or more inwards upon the neck of the scapula; it thus allows of the synovial lining of the capsule forming quite a pouch upon the fore and inner aspects of the root of the coracoid. In other cases, however, the capsule does not extend further than a quarter of an inch beyond the articular margin on this aspect of the joint. Below the glenoid fossa the capsule blends with the origin of the long head of the triceps which arises from the axillary border of the scapula right up to the border of the glenoid ligament, and as the muscle passes downwards and outwards its sheath is attached to the under side of the capsule.

At the humerus the upper half is fixed to the anatomical neck of the bone—*i.e.*, to the groove between the tuberosities and the margin of the articular head; between the tuberosities it sends down over the bicipital groove and biceps tendon a thick prolongation, which gradually attenuates as it descends. The lower half of the capsule descends upon the humerus further from the margin of the articular facet, but some of the deeper fibres are reflected upwards so as to be attached close to the articular margin, and they thus form, but to a much slighter degree, a kind of fibrous investment for this part of the neck of the humerus, as fibres similarly reflected in the capsule of the hip, do for the cervix femoris.

The tendons of the shoulder muscles which pass outwards over the capsule from the dorsal and ventral surfaces of the scapula to be inserted into the tuberosities of the humerus, strengthen the capsule very considerably, more especially near their insertions, and are chiefly instrumental in holding the head of the humerus against the cavity of the scapula.

With care, however, the tendons of the three muscles inserted into the great tuberosity can be separated from the capsule right onwards to their bony attachment; generally also this can be done with the tendon of the sub-scapularis. Sometimes, when the bursa between this tendon and the neck of the scapula communicates with the synovial sac of the joint, the capsule beneath the tendon is very thin and can only with difficulty, if at all, be separated from it.

Where the sub-scapularis is inserted into the lesser tuberosity there is sometimes a well-formed sesamoid bone, the size of a flattened marble, with a polished surface next the tuberosity. More often than not, however, the capsule is as thick on its inner aspect as on its outer, and I have sometimes seen the inner portion below the border of the sub-scapularis the thickest part of the whole capsule, while the outer has been very thin. At any rate there is no one area of this capsule which is constantly so different from the rest in density and strength, as is the case with the hip-joint capsule, and the reason is clear. In the hip-joint the greater thickness of certain portions of the capsular ligament is requisite for steadiness and support, and to economise muscular action, but in the shoulder-joint nothing like the same degree of steadiness or strength is wanted, as the upper limb of man serves not the purpose of bearing weight, but is almost solely designed for rapidity and extensive range of movement.

The Coraco-humeral Ligament.—One portion of the capsule is strengthened by a superadded band, which deserves the honour of a special name. This passes from the coracoid process to the greater tuberosity, and is hence called the coraco-humeral band or ligament. To see it satisfactorily, all the other soft parts must be removed from the joint, and the ligamentous tissue alone left. Though not completely separated from the rest of the capsule, it is quite a distinct process of ligament. It is attached above to the outer edge of the root and horizontal arm of the coracoid process, nearly up to its tip, and from the dorsal aspect of the scapula looks like an uninterrupted continuation of the back of the capsule. When seen from the ventral surface, it looks like a fan-like prolongation above the rest of the ligament. Having passed over the capsule along the line of the biceps tendon, it is inserted into the outer tuberosity of the humerus, and assists the capsule, with which it becomes incorporated, to bridge over the bicipital groove.

The Gleno-humeral Process of the Capsule.—Besides the coraco-humeral ligament above described, the capsular ligament is sometimes said to be strengthened by three accessory bands or supplemental sets of fibres, passing from the scapula to the humerus. One of these extends from the inner edge of the glenoid cavity, along the lower edge of the sub-scapularis tendon, to the lower part of the small tuberosity; another passes from the under edge of the cavity to the under part of the neck of the humerus, thickening the lower surface of the capsule, and is the part put on stretch when the arm is fully raised; and a third, seen only from within the capsule, extends along the inner edge of the biceps tendon. Although there is nearly always to be seen along the two first-mentioned lines some thickening of the capsule, yet this is usually but slight, and the extra fibres producing it do not deserve a separate name. But the thin narrow riband-like slip which runs along beside the biceps tendon, and which has been styled the *gleno-humeral ligament*, deserves a brief notice. After laying open the capsule freely on the ventral side, it is found to be attached above to the edge of the glenoid fossa at the root of the coracoid, and below to the lesser tuberosity of the humerus. It presents two sides free, and covered by synovial membrane; one edge, thin and sharp, projecting outwards a little way under the tendon of the biceps, and another attached to the deep surface of the capsular ligament. It thus helps to form a groove or sulcus for the biceps tendon, keeping it in its proper line as it traverses the capsule, and checking any tendency to its inward displacement.

It is supposed to correspond to the ligamentum teres of the hip-joint of man, and to the ligamentum teres of the shoulder-joint of the frog. As the ligamentum teres is, however, quite a superfluous and unnecessary structure in the hip, it is still more difficult to understand what purpose, as its homologue, this gleno-humeral slip can serve in the shoulder; and it seems to me that its only use is, as I have pointed out above, to form a sulcus in the interior of the capsule for the play of the biceps tendon. It is sometimes described as a part of the coraco-humeral ligament, but as that ligament is superadded to the capsule on its exterior, and the gleno-humeral is a process from its interior, this view is incorrect unless the whole thickness of that particular area of the capsule be considered coraco-humeral ligament, which in the above description is not the case.

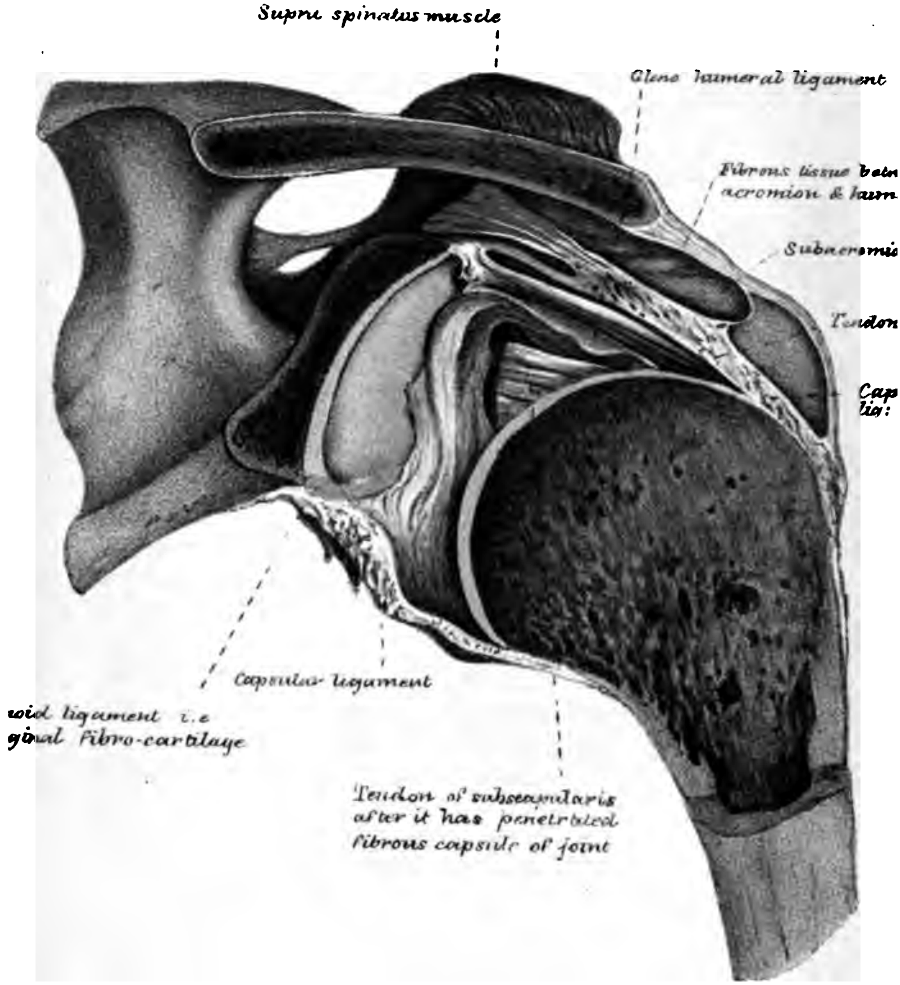
Besides the support which the capsule receives from the tendons of muscles, extra strength is given to it by a strong fascia, which passes over it from the under surface of the acromion and coracoid processes, as well as by a fascia from the anterior part of the coraco-acromial ligament immediately beneath the deltoid muscle.

The glenoid ligament is a narrow rim of dense fibro-cartilage, which is attached to and deepens the circumferential portion of the glenoid socket. Its structure is almost entirely fibrous, with but few cartilage cells intermixed, and the fibrous bundles are circularly disposed, and more or less interlacing.

It is about one-fourth of an inch wide above and below, and usually not much more than half that width along the outer and inner borders of the socket. Its outer edge is one-eighth to one-fourth of an inch deep, and is inseparably welded, near its attachment to the bone, with the fibres of the

PLATE XX

VERTICAL SECTION THROUGH SHOULDER JOINT



A. Hensman del. ad. nat.

West, Newman & Co lith.

capsular ligament. The inner edge is thin, and in contact with the articular cartilage; in some places, especially above and along the inner side, it often overlaps the cartilage, and forms quite a long loose irregular fringe; at others it is separated by a very narrow interval covered with fibro-cartilage of a more loosely woven character, so that the line of demarcation between articular cartilage and fibro-cartilage is usually quite evident to the naked eye.

At the upper part of the fossa the biceps tendon is prolonged into the glenoid ligament, and forms an integral and important part of it. Sometimes the fibres of the tendon curve along the outer, sometimes along the inner, and sometimes again along both outer and inner sides for a considerable distance. Indeed, the tendon sends into the ligament fibres which wind round nearly the entire circumference of the socket.

The *articular cartilage* covering the glenoid socket is thicker at the circumference than in the centre. In the former situation it is about three lines in depth, in the latter less than two lines. It thus assists the glenoid ligament to deepen the fossa for the head of the humerus. It is generally thickest of all at the lowest part of the fossa, for it is here that the head of the humerus revolves when the arm is raised by the deltoid muscle; and against this part of the socket the head of the bone is pressed by the action of the subscapularis, infra-spinatus, coraco-brachialis, and the biceps tendons. Over the head of the humerus the articular cartilage is thickest at the centre and a little below the centre, for it is this part of the head of the bone which is in contact with the socket whilst the the arm is raised, and the shoulder muscles are therefore in action, to press the surfaces closely together.

The Biceps Tendon.—This tendon forms a peculiar feature in the shoulder-joint, as it traverses it from the glenoid fossa to reach the upper end of the bicipital groove in the humerus. While it is covered by the fibrous capsule it lies first in a sulcus of the capsule formed, as described above, by the projecting gleno-humeral band, and then in the groove between the tuberosities of the humerus. It passes over the head of the humerus a little on the inner side of its summit; and, until it reaches the bicipital groove in that bone, where it changes to a rounded form, it is flat, with one surface looking to the

the joint beneath the muscles, and some of them send branches into the bone on the dorsal aspect near the margin of the glenoid fossa.

The *anterior circumflex* supplies the inner, front, and lower parts of the capsule, while a branch passes upwards from it to the joint along the bicipital groove. A branch which passes beneath the lower border of the sub-scapularis, near its insertion, supplies the subjacent part of the capsule. Sometimes there are two anterior circumflex arteries, one of which is distributed entirely to the joint which it reaches along the lower border of the sub-scapularis, while the other passes outwards upon the latissimus dorsi tendon to get beneath the coraco-brachialis, where it sends branches upwards and downwards along the biceps tendon.

A branch of the anterior circumflex pierces the humerus at its anatomical neck on the inner side of the bicipital groove.

The *posterior circumflex* gives off a branch which runs forward beneath the deltoid towards the great tuberosity of the humerus, and then courses upwards, ramifying over the outer and front parts of the capsule, and anastomosing with the anterior circumflex and supra-scapular vessels. A branch from the posterior circumflex to the teres minor runs on to the capsule, and another passes beneath that muscle to supply the humerus, and the capsule near its attachment to the humerus.

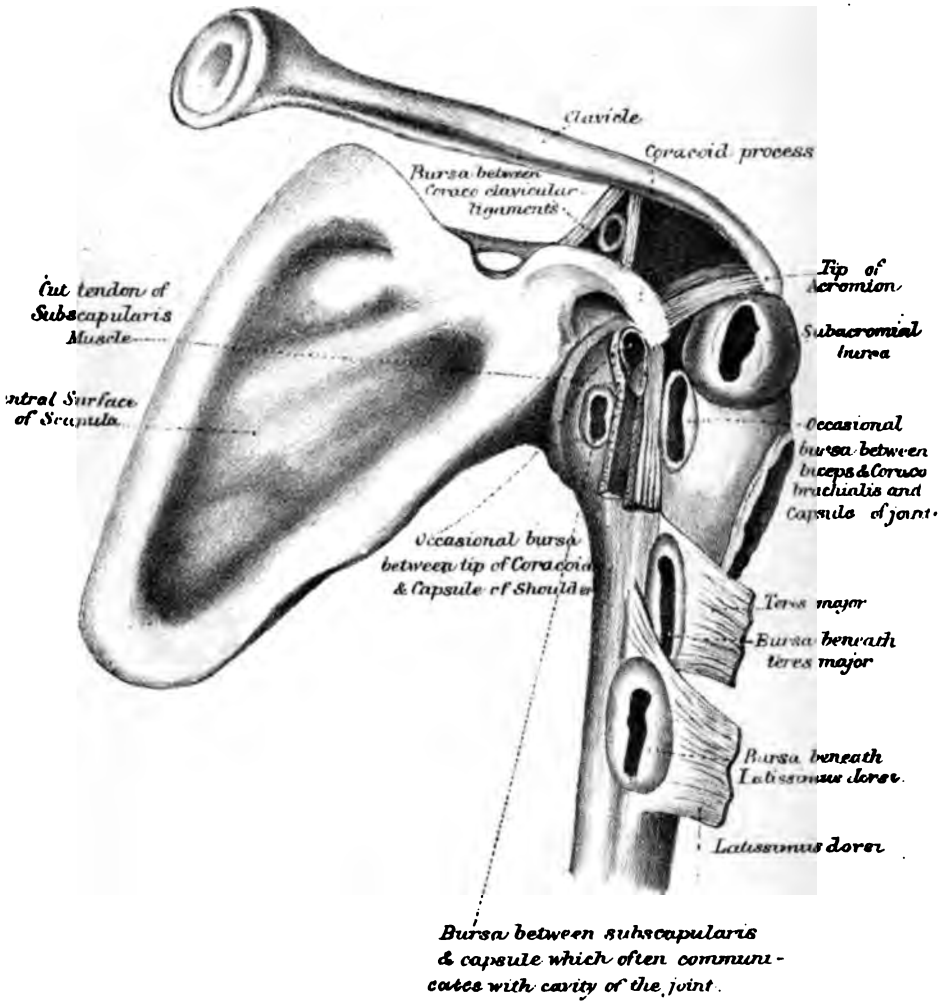
The *dorsalis scapulæ artery*, whilst in the substance of the teres minor, sends up branches to the lower and outer part of the joint.

The *subscapular artery* supplies the inner side of the capsule near the glenoid fossa. One long branch usually runs upon the anterior surface of the long head of the triceps, and under cover of the sub-scapularis, to supply the capsule and the bone near the attachment of the capsule, and then ramifies on the venter of the scapula. A small twig from this branch usually pierces the scapula near the glenoid fossa.

A considerable branch from the *second part of the axillary artery* runs over the anterior surface of the sub-scapularis muscle to its upper border, and then reaches the capsule beneath the origin of the coraco-brachialis and biceps, and the coracoid process.

THE NERVES.—The *supra-scapular nerve* gives off a branch

BURSÆ IN CONNECTION WITH SHOULDER JOINT.


Clavicle
Coracoid process
Bursa between Coraco clavicular ligaments
Tip of Acromion
Cut tendon of Subscapularis Muscle
Subacromial bursa
ntral Surface of Scapula
Occasional bursa between biceps & Coraco brachialis and Capsule of joint
Occasional bursa between tip of Coracoid & Capsule of Should
Teres major
Bursa beneath teres major
Bursa beneath Latissimus dorsi
Latissimus dorsi
Bursa between subscapularis & capsule which often communicates with cavity of the joint.

Hensman del. after Monro *West, Newman & Co. Lith.*

or two, to the shoulder, whilst in the supra-spinous fossa; the nerve then passes through the great scapular notch into the lower fossa, giving off other twigs to enter the joint, and some which penetrate the scapula.

The *circumflex nerve*, after springing from the posterior cord of the brachial plexus, winds round the joint beneath the deltoid muscle; as it does so, it supplies twigs to the capsule. Other branches from it enter the capsule at the lower border of the sub-scapularis muscle.

The *subscapular nerves* also give branches to the interior of the joint; the upper one penetrates the upper part of the subscapular muscle to reach the capsule, and the middle gives off a twig at the lower edge of the muscle.

The nerve supply of the shoulder-joint is thus derived from the same source as the supply to the shoulder muscles. The supra- and infra-spinatus are supplied by the supra-scapular; the sub-scapularis by the subscapular; and the deltoid and teres minor, together with the skin over the shoulder muscles, by the circumflex.

THE BURSÆ.—There are several bursæ in connexion with this joint.

(1) The largest, and the one most frequently brought under the notice of the surgeon, is situated between the acromion and coraco-acromial ligament above, and the capsular ligament of the shoulder below. In elderly people, this bursa sometimes communicates through a large irregular opening with the synovial cavity of the joint.

(2) A large bursa exists beneath the sub-scapularis, between it on the one hand, and the neck of the scapula and inner side of the capsular ligament on the other. It very frequently communicates with the cavity of the joint, but not so constantly as it is sometimes stated to do.

(3) Occasionally there is another and a much smaller bursa placed further out upon the capsule, between it and the subscapular tendon. This, when it is present, generally communicates with the joint.

(4) A small bursa, sometimes wanting, is interposed between the under surface of the tip of the coracoid process and the capsule.

(5) Another elongated bursa, similar in shape to, but a little

larger than the last, and like it sometimes wanting, is often situated between the united coraco-brachialis and biceps tendons, and the capsular ligament of the shoulder.

In addition to the above, three other bursæ, though not directly placed over the capsule, are yet in near relation to it.

These are (6) a bursa between the tendon of the teres major and the humerus on the one side, and the upper part of the latissimus on the other. (7) One between the tendon of the latissimus dorsi and the humerus; (8) and one between the tendon of the biceps and the humerus.

The Muscles.—It must here be observed, that in no other joint in the body do the muscles add so greatly to the strength of the articulation, or take so large a share in controlling movements, in keeping the bones in normal apposition, and in preventing their displacement, as at the shoulder. Four muscles may be said to be inserted into the capsule; whilst another passes beneath it, and acts like a strap to prevent upward as well as lateral displacement, and yet at the same time acts as a sling to hold the bone upwards against the humerus.

There is a close similarity between the shoulder-joint and the hip, in the way in which the muscles are disposed about the capsule. Thus, on the outer or extensor side of the shoulder we have the supra- and infra-spinatus and the teres minor; at the corresponding aspect of the hip, there are the pyriformis, gemelli and obturator internus. On the flexor or anterior side, the sub-scapularis covers the shoulder; the ilio-psoas the hip: while the long head of the rectus femoris bears somewhat the same relation to the capsule of the hip as the long tendon of the biceps does to the shoulder; and the deltoid covers over the whole of the upper and outer side of the shoulder, as the glutæi do the hip. As in the hip, so in the shoulder, the portion of the capsule least supported by muscles is the lower or inner side. Here, too, the shoulder capsule is often very thin, and there is no projecting bony prominence like the acromion and coracoid, to counteract the deficiency of the muscular support in bearing the pressure of the head of the humerus in states of abduction. Hence abduction in the case of the shoulder, as well as of the hip, is the position of least safety, and the one in which dislocation nearly always occurs.

The muscles which effect the various movements of the shoulder may be grouped according to their action into flexors, extensors, abductors, adductors, and rotators, although it must be premised that some of the muscles can produce different, though not of course contrary actions, according to the action of other muscles wherewith for the time they are associated, and some combine movement in two directions.

Flexors.—The carrying forward of the humerus constitutes flexion; it is a much freer movement than its opposite, extension, and is produced by the pectoralis major, the anterior fibres of the deltoid when acting alone, the coraco-brachialis, and long and short tendons of the biceps; and when the arm is raised from the side, *i.e.*, abducted, by the sub-scapularis also.

Extensors.—Extension, or the movement of the arm backwards, is effected by the latissimus dorsi, the posterior fibres of the deltoid when acting alone, and, when the arm is raised, by the infra-spinatus.

The movements of flexion and extension, or the swinging to and fro, of the humerus, are made more free than they otherwise would be by the forward and backward, and rotatory movements of the scapula. This is more particularly the case with flexion, the scapula following the head of the humerus so that the muscles which have been enumerated as moving the scapula forwards come into associated action with the flexors; and the muscles which withdraw the scapula after it has been advanced with the extensors.

Abductors.—Abduction, or the movement of the humerus away from the side of the body, is accomplished by those muscles which elevate the arm, of which the chief is the deltoid. The supra-spinatus is a simple elevator or abductor. The deltoid and supra-spinatus can raise the humerus to a right angle with the trunk; any further elevation is produced by the action of the trapezius upon the scapula, and is not a movement of the shoulder-joint.

Adductors.—Adduction, or drawing the arm to the side and therefore depressing the raised arm, may be accompanied either with flexion or extension.

The adductors which draw forwards are the pectoralis major and the coraco-brachialis and biceps.

The adductors that draw the humerus backwards are the latissimus dorsi and the teres major and minor. The long head of the triceps adducts the arm after it has been abducted.

Rotators.—Rotation inwards is effected by the sub-scapularis, and to a less extent by the latissimus dorsi and teres major, when the arm hangs by the side.

Rotation outwards by the teres minor and infra-spinatus, when the arm is hanging by the side.

Circumduction is effected by the quick succession of the four angular movements.

THE MOVEMENTS.—In the shoulder-joint there are the common angular movements in four directions: viz., flexion, extension, abduction, and adduction; the combination of these in quick succession, which is called circumduction; and rotation. Flexion is the swinging forwards, extension the swinging backwards of the humerus; abduction is the raising of the humerus from, adduction the depression of it to, the side of the body.

In flexion and extension the head of the humerus moves on the centre of the glenoid fossa round an oblique line corresponding to the axis of the head and neck of the bone. Flexion is more free than extension, and in extreme flexion the scapula follows the head of the humerus so as to keep the articular surfaces together. In extension the scapula moves much less, if at all. In abduction and adduction the scapula is fixed, and the humerus rolls upwards and downwards upon its fossa; during abduction the head descends until it projects beyond the lower edge of the glenoid socket against the capsule, and the great tuberosity impinges against the arch of the acromion; during adduction the head of the humerus ascends upon the socket, the arm at last reaches the side of the trunk, and the capsule is completely relaxed.

In circumduction the humerus by passing quickly through the several angular movements describes a cone, whose apex is at the shoulder-joint and whose base is at the condylar extremity; or if we consider the movements at the shoulder-joint as of the whole upper limb, the base is at the terminal phalanges of the fingers.

Rotation is movement round a vertical axis through the extremities of the humerus from the point of the head to the inner condyle. In rotation forwards, *i.e.*, inwards, the head of the bone rolls backwards on the socket, as the great tuberosity and the shaft are turned forwards. In rotation backwards, *i.e.*, outwards, the head of the bone glides forwards on the glenoid cavity, and the tuberosity, shaft, and lower end of the humerus are turned backwards, *i.e.*, outwards.

Great freedom of movement is permitted at the shoulder, and greater freedom is added by the free-play mobility of the scapula. Restraint is scarcely at all exercised upon the movements of the shoulder proper by the ligaments, but chiefly by the muscles of the joint. In abduction the lower part of the capsule is somewhat, and in extreme abduction considerably, tightened; in rotation inwards and outwards, the upper part of the capsule is made tense. The movements of abduction and extension have the most decided and definite resistance offered to them otherwise than by muscles and the shoulder-joint ligaments, for the great tuberosity of the humerus by striking against the acromion process, and the coraco-acromial ligament, stops short any further advance of the bone in these directions, and thus abduction ceases altogether as soon as the arm is raised to a right angle with the trunk; and extension shortly after the humerus passes the line of the trunk. The further elevation of the arm is effected by the rotation of the scapula round its own axis by the action of the trapezius muscle upon the sterno-clavicular and acromio-clavicular joints. The insertion of the trapezius muscle, as is well known, is along a bony line parallel with that from which the deltoid arises; the fibres of the muscles are in the same continuous lines, and the spine of the scapula, the acromion, and clavicle may be looked upon simply as a bony interruption of the fibres of these two muscles. The trapezius therefore is well adapted to continue the direction of the motion of the deltoid after the action of the latter is completed.

The acromion and coracoid processes together with the ligament which extends between them form an arch, separated by a bursa from the capsule of the shoulder. Beneath this arch the movements of the joint have to take place, and against it the head and tuberosities are pressed when the weight of the trunk rests upon the arms; and the great tuberosity and upper part of the shaft impinge upon it when abduction and extension are carried to their fullest extent.

The movements of the shoulder, like those of the other joints of the upper limb, are used as aids to words and looks in giving expression to the feelings and emotions of the human mind. We see force and emphasis added to the speech of the orator, and to the representation of passions by the actor or actress by these movements. It is not easy to specialise in any decided manner, but it may be stated, with some approach to truth, that the portrayal of feelings of a widely impressed kind, whether it be of despair, resignation, admiration, entreaty, or love, is assisted by movements which occur at the shoulder, often in combination with those effected at the wrist. So again in the more concentrated and decisive states of mind, as when we give a command, a dismissal, or definite instructions with dignity or firmness, the shoulder movements are employed, with others of the wrist and index-finger, the elbow all the time remaining rigid, or moving but slightly.

CHAPTER XII.

THE ELBOW-JOINT.

Class, **Diarthrosis.** *Subdivision*, **Ginglymus.**

THE elbow is a complete hinge joint, and, unlike the knee, depends for its security and strength upon the configuration of the bones rather than on the number, strength, or arrangement of the ligaments.

The bones composing it are the lower end of the humerus above, and the upper ends of the radius and ulna below; the articular surfaces of the former being received partly *within* the great sigmoid cavity of the ulna, and partly *upon* the cup-like surface of the head of the radius.

THE HUMERUS presents at its lower extremity two condyles, with a remarkable double articular surface intervening between them. The shaft, which is cylindrical in its upper two-thirds, becomes flattened antero-posteriorly at the lower end, where it measures from point to point of the condyles from two and a half to three inches across; from before backwards it varies in thickness at different spots, being in places quite translucent, and nowhere more than one inch through. It curves forwards a little from the shaft, and presents, when looked at from in front, two sharp, strong lateral ridges, separating the anterior from the posterior surface; and a median ridge running down the centre of the anterior surface of the shaft, which bifurcates just above the articular surface so as to enclose the coronoid fossa. When seen from behind, the bone is flat above the olecranon fossa, but articular below it; rough and bevelled forwards over the outer condyle; flattened and grooved over the inner condyle. The external ridge, called usually the external condyloid ridge, is by far the most prominent; it terminates at the external condyle, and may be traced up to the back of the great tuberosity. The internal condyloid ridge terminates at the inner condyle, and may be traced up to the root of the lesser tuberosity. The anterior or supra-trochlear ridge ascends to the anterior border of the great tuberosity, and the ridges into which it bifurcates below terminate, the one at the outer, the other at the inner border of the trochlear facet for the ulna. All these ridges assist in conducting forces from the elbow to the shoulder-joint; but the condyloid ridges, with the flattened bone between them, serve also to divide off sharply the muscles behind which extend, from those in front which flex the elbow.

The two projections in which the lateral ridges end are the *condyles;* these are very different from the condyles of the femur, which afford large articular surfaces for the tibia. The condyles of the humerus are merely bony tubercles for the advantageous origin of muscles, and do not enter at all into the immediate formation of the elbow. They do not descend quite to the lowest extremity of the bone, so that the articular surface reaches beyond them.

The *inner condyle* is much the most prominent, and gives rise to the flexors and pronators—the strongest sets of muscles of the forearm. It also descends somewhat lower than the external, and projects horizontally inwards for three-quarters of an inch or more, beyond the inner margin of the trochlea. Between it and the trochlea in front is a rough, narrow depression, and below and behind it is a deep and narrow groove, along which the ulnar nerve passes over the elbow-joint. The *outer condyle* gives rise to the extensor muscles—a much less powerful set than the flexors. It projects less than a quarter of an inch beyond the outer edge of the capitulum, in front; and about three-quarters of an inch beyond the outer margin of the trochlea, behind.

The *articular surface* at the lower end of the humerus is situated between the condyles, extends round the extremity upon both aspects of the bone, and owing to the obliquity of the bone descends lower on the inner than on the outer side. It is divided in front and below by a shallow groove, which separates a small external and globular portion about the size of a large cherry—the capitulum or capitellum—from a wide pulley-like and oblique surface, called the trochlea.

The *capitulum,* or lesser head, does not extend at all upon the posterior surface of the humerus, but is seen only on the anterior surface, and at the end. It articulates with the cup-like facet at the top of the radius, and the groove between it and the trochlea receives the inner margin of the rim of the radial facet. In complete extension of the joint, when pressure is not directed upon the lower end of the bone, the radius is not in contact with the capitulum at all, and the posterior margin of the rim projects beyond it. During flexion the bones come more and more into apposition, and in complete flexion the anterior portion of the rim of the radial cavity sinks into the curved shallow fossa above the capitulum.

The *trochlea* extends equally over front and back surfaces, as well as upon the extremity. It is convex from before backwards, concave from side to side, and wider by about an eighth of an inch in front than behind. It is bounded by two margins, the outer of which is but slightly prominent in front and below, but becomes sharp and pronounced behind. Immediately to its outer side is the groove separating the capitulum from it. The inner margin is thick, strong, prominent, and descends lower than the outer. The groove between these margins extends from the coronoid fossa in front to the olecranon fossa behind, and in doing so is inclined obliquely outwards. Owing to the obliquity of the humerus, and the greater prominence of the inner margin of the trochlea below as well as in front, the shaft of the bone, when held with its lower end resting upon a flat surface, slants very considerably outwards. From within outwards we find the articular surface of the lower extremity presents, first, the trochlea with its prominent inner border, its deep groove, and less well-marked outer border; next, the groove between the trochlea and capitulum, which receives the inner margin of the cup-like cavity of the radius; and lastly, the capitulum, which receives the cup-like cavity itself.

Above the articular surface, behind, is the large *olecranon fossa*, which receives the olecranon process of the ulna in extension of the forearm. It is a deep, oval-shaped, transversely elongated fossa, to which the posterior ligament is attached, and in which is lodged a quantity of articular fatty tissue. Above the articular surface in front are two fossæ. One, the larger—*fossa anterior major*—is placed immediately above the groove of the trochlea, and between the bifurcated lower ends of the supra-trochlear ridge; it is large enough to admit the tip of the finger, receives the coronoid process in flexion, and lodges articular fat. The other fossa—*fossa anterior minor*—

is a narrow, shallow, and crescentic depression above the capitulum, which receives the anterior margin of the cup-like cavity of the radius in extreme flexion. The thin lamina of bone separating the olecranon from the coronoid fossa is often perforated by a hole of some size.

THE ULNA is of large size at its upper extremity, where it forms a very important part of the elbow-joint, as well as of the superior radio-ulnar articulation. It presents two articular facets, the large and the small sigmoid cavities, and two upstanding processes, each of which assists in forming the large sigmoid cavity; whilst by their non-articular surface, the larger of these gives attachment to the extensor, and the smaller to the chief flexor muscle of the forearm.

The *great sigmoid cavity* is a large semilunar excavation formed by the anterior surface of the olecranon, the superior surface of the coronoid process, and the end of the shaft of the ulna, which intervenes between them. It is concave from above downwards, and measures from one and a half to two inches along the middle of its surface; convex from side to side, and measures about one inch and an eighth across, near the top of the olecranon, about one inch across at the base of the coronoid process, and about seven-eighths of an inch, though oftentimes very much less, where the olecranon joins the shaft. Dividing the cavity into two vertical portions is a prominent smooth ridge, which extends from the tip of the olecranon to the tip of the coronoid. The surface on the inner side of the ridge is larger than that on the outer side. Dividing the cavity into two transverse portions is a notch or constriction in each lateral border opposite the junction of the olecranon with the shaft; and between the notches a depression, in which there is often no articular cartilage. The portion of the fossa above this depression is formed entirely by the olecranon, and is more extensive both vertically and transversely than the part in front. The portion of the fossa in front of this depression is formed by the end of the shaft, and the upper surface of the coronoid process, of the ulna. The notch and outer end of this depression separate widely the lesser sigmoid cavity from the facetted surface of the olecranon. Sharp and projecting margins limit the great sigmoid fossa everywhere, except on the outer side of the portion formed by the shaft. Here the articular cartilage extends over a well-defined, but not projecting, edge into the lesser sigmoid cavity for the radius. The lesser sigmoid cavity will be described under the superior radio-ulnar articulation.

The *olecranon* is a large square-shaped process connected by one of its surfaces with the summit of the ulna. It forms the strong, posterior bony part of the elbow. It bends forward at the top, so that the edge which separates the superior from the anterior surface somewhat overhangs the great sigmoid cavity, and terminates in a central tip, which during extension of the forearm rests against the floor of the olecranon fossa of the humerus.

The superior surface is irregularly quadrilateral, and gives attachment to the posterior ligament of the joint, and behind that to the extensor triceps muscle; a bursa intervening between them.

The posterior surface has marked upon it two ridges, which meet upon the top of the shaft, and to which are fixed processes of the triceps tendon.

The triangular surface enclosed between them is subcutaneous, but gives attachment to strong longitudinal fibres connected with the triceps tendon, and over it a bursa is placed; in front of the outer ridge, the anconeus is inserted; from the depressed surface of bone in front of the inner edge, the flexor profundus digitorum arises.

The *coronoid* is a much smaller process than the olecranon, and ascends from the front of the shaft with a slight inclination forwards. It is triangular in shape, with its upper or posterior surface forming part of the great sigmoid cavity; and its anterior surface rough, for the attachment of the anterior ligament of the elbow and the brachialis anticus muscle. Its superior edges, which meet at the tip of the coronoid process, slope gradually into the edges of the free end of the shaft; the outer one changes its direction, after bounding the sigmoid fossa in front for a little way, and then passes vertically downwards, limiting the lesser sigmoid cavity. Where the edges of the coronoid process meet with the edges of the portion of the fossa formed by the shaft, two ridges start, and descending downwards a little way, meet each other on the front surface of the shaft; thus the front surface of the coronoid being limited by these edges and ridges, presents an irregularly diamond shape, into the lower two-thirds of which the brachialis anticus is inserted, as well as into the upper end of the shaft of the ulna.

At the top of the shaft, to the inner side of the coronoid process, and widening the inner portion of the great sigmoid fossa, there is a projection which overhangs the deep depression on the inner surface of the shaft, from which the flexor profundus digitorum arises.

THE RADIUS.—The upper extremity of the radius presents a circular head supported upon a smooth and constricted neck. The *head* is hollowed out a little at its free end into a shallow cup-like depression, which receives the capitulum of the humerus in certain positions of the joint. The margins of the cup are raised and rounded off, and pass over on to a smooth cartilage-covered vertical border, which is surrounded in the recent state by the annular ligament. This border at some parts is not more than one-fifth of an inch deep, but on the inner side, where the radius articulates with the lesser sigmoid cavity of the ulna, it descends in some cases fully half an inch. Below the cartilage-covered vertical border the radius suddenly contracts into a smooth constricted neck.

The *neck* is about an inch long and inclines a little inwards, so as to form with the shaft a curve having the convexity directed inwards. On this convexity is a rough tubercle, which at its posterior part gives insertion to the biceps tendon, whilst over the anterior portion a bursa is interposed between the tendon and the bone.

THE LIGAMENTS OF THE ELBOW-JOINT.—The ligaments of the elbow-joint are so arranged as to form one large and capacious capsule, which encloses the articular surfaces, and something more, of the adjoining ends of the humerus, ulna, and radius. It may indeed be said to embrace not only the elbow but also the superior radio-ulnar articulation, and to unite them into one joint; and this is due to its being fixed round the neck of the radius after being intimately blended with the coronary ligament.

This capsule is, however, strengthened very considerably at the sides by some strong superadded fibres, or fasciculi of fibres, which arise from the condyles of the humerus and spread out upon the capsule, so as to be quite inseparable from it, as they descend to the bones of the forearm. On this account, no doubt, it is that the elbow is usually described as having an anterior, a posterior, and two lateral ligaments; a mode of description which is objectionable, as it leads to the supposition that there are four distinct ligaments, whereas they are but areas or portions of one continuous structure. Though in the following account, for the sake of convenience, the attachments of the capsule on the different aspects will be spoken of separately, the four segments will be described as parts of the capsule, and not as separate and distinct ligaments.

The *anterior segment of the capsular ligament* is attached to the front of the humerus above its articular surface, and the coronoid fossa, in an inverted V-shaped manner. There are generally to be traced at the lower end of the dry bone (and it will become apparent at once when the dissected joint is examined at the same time as the dry bone) two faintly marked ridges, of which the lower ends reach to the point of the external and internal condyles respectively, and the upper meet at a variable distance, from half an inch to an inch, above the coronoid fossa. To these ridges the front of the capsule is attached above. Below, *to the ulna,* it is fixed to a faintly marked and nearly transverse ridge on the front of the coronoid process, which is on a level with, or somewhat below the smooth outer border of the great sigmoid cavity; and *on the radius,* it reaches to the neck of the bone a little way below the vertical margin of the head. It is very intimately connected with the orbicular or annular ligament.

It is of varying thickness and strength, sometimes being so weak and thin as barely to cover the synovial membrane and fatty tissue near the coronoid fossa. At other times it is thick and strong, and consists of coarse decussating fibres, the chief of which pass from above and within, downwards and outwards to the radius; whilst other fibres descend vertically from above the coronoid fossa to the ulna, and others again pass downwards and inwards to the ulna.

This portion of the capsule is tightened in extension, and as extension proceeds it becomes very much stretched over the prominent inner border of the trochlea; during flexion it becomes transversely wrinkled, but is prevented from being squeezed between the apposed surfaces of the bones by falling over the front of the radius and ulna near the line of attachment of the capsule to the humerus.

The *posterior portion of the capsular ligament* is thin and membranous, and is attached *superiorly* to the humerus in much the same inverted V-shaped manner as the anterior. It reaches upwards from the back of the internal condyle along the inner edge, nearly to the top, of the olecranon fossa; then it is fixed to a line passing transversely across the upper portion of the fossa till it reaches the outer edge, along which it is also attached; next it is attached in a continuous line to the back of the external condyle as far down as the rough surface a little external to the angle between the trochlea and hinder border of the capitulum; and finally it curves forwards along the posterior edge of the capitulum. *Inferiorly*, it is attached to the superior and external surfaces of the olecranon, at a considerable distance from the articular margin of the ulna; to the rough surface of the ulna behind the lesser sigmoid notch; and to the upper end of the ridge which separates the anconeus from the supinator brevis muscles, and runs downwards upon the shaft from the hinder margin of the notch; and lastly, it is connected with the back part of the neck of the radius and with the coronary ligament, with which it blends as it passes over it.

This portion of the ligament is composed partly of decussating fibres, most of which pass vertically from their upper to their lower attachment, many obliquely downwards and inwards from the external condyle to the back of the lesser sigmoid cavity of the ulna and the neck of the radius; whilst others, again, take a transverse course superficial to, and decussating with the rest, from one border of the olecranon fossa to the other. This part of the capsule is usually weaker than the anterior, and often is especially thin near the top of the olecranon fossa. It is made tight during flexion, and is thrown into numerous transverse folds, which are pushed upwards by the point of the olecranon during extension.

The *internal portion of the capsular ligament*, like the external, is much thicker, denser, and stronger than either the anterior or posterior. It is triangular in form, with its apex above, and its base, which is curved, below. It is attached to the humerus on the anterior and under aspect of the internal condyle, and to the condyloid edge of the groove between the trochlea and condyle; and the fibres radiate as they pass to their insertion into the inner side of the shaft of the ulna and of the olecranon.

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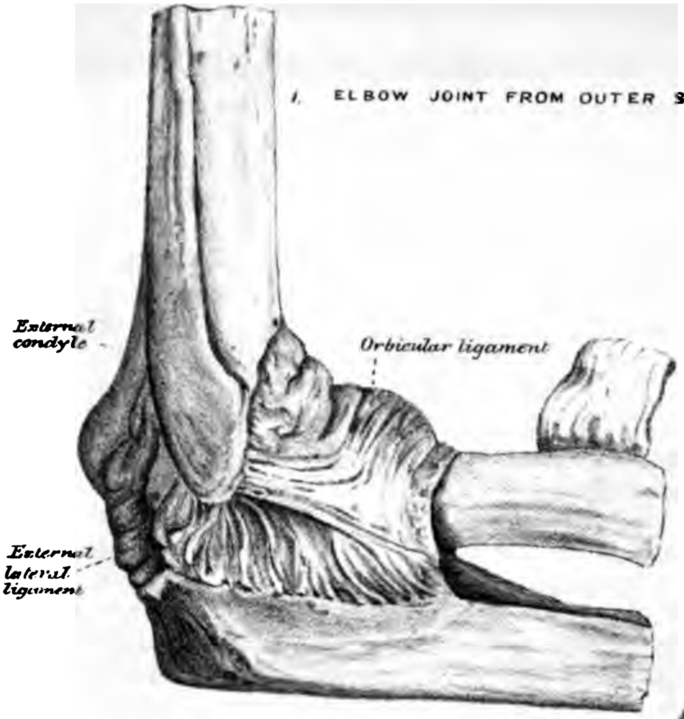
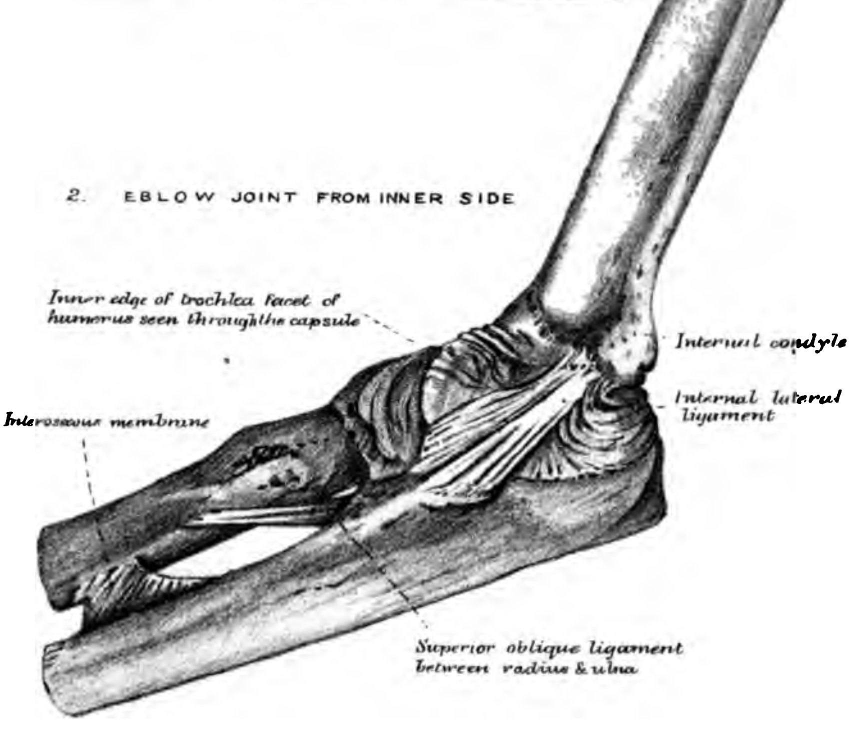
PLATE XXII.



1. ELBOW JOINT FROM OUTER SIDE



2. EBLOW JOINT FROM INNER SIDE

Inner edge of trochlea facet of humerus seen through the capsule
Internal condyle
Internal lateral ligament
Interosseous membrane
Superior oblique ligament between radius & ulna

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West, Newman & Co

The anterior set of fibres pass forwards as they descend to the rough overhanging and projecting edge of the sigmoid cavity at the inner side of the coronoid process. The middle set descend less obliquely, and some of them quite vertically from the under edge of the internal condyle to a ridge on the ulna, which curves upwards between the coronoid and olecranon processes; and the posterior set pass obliquely backwards to be attached to the inner surface of the olecranon, at a short distance from the articular margin. The anterior set are much the thickest, strongest, and most pronounced, and like the *anterior portion of the capsule*, they become tight during extension. The posterior set are associated in action with the *posterior portion of the capsule*, and become tense only on flexion; whereas the middle fibres, owing to their points of attachment being in or near the axis of motion of the joint, are, like most lateral ligaments, tight in every position.

The *external portion of the capsule* is attached above to the lower portion of the external condyle, and to the bone in front between it and the capitulum, for a little way. Its fibres radiate to their attachment into the outer side of the neck of the radius, and the coronary ligament. The anterior fibres advance farther in front of the joint, than the posterior ones recede upon the back of it. This part of the capsule is strong and well-marked, though less so than the internal lateral portion. Many of the fibres, for the same reason as applies to the central set of the inner segment of the capsule, are tight in every position of the forearm; whereas the rest, being for the most part attached in front of the condyle, and the condyle being a little in front of the axis of motion, are rendered tense during extension.

The Fatty Cushions or Pads, within the Joint.—Outside the synovial membrane, there is in several places a quantity of soft fine fatty tissue, which forms often large pads or cushions at certain spots. The most constant of these are one at the notch in the great sigmoid cavity at the base of the olecranon, and the other along the outer side of the olecranon, projecting into the cavity between the ulna and radius. (They are well shown in the coloured plates of the elbow-joint.) The latter, together with a fold of synovial membrane, which generally exists opposite the front part of the outer lip of the trochlea of the humerus, suggests a division of the synovial cavity of the joint into two parts—viz., 1, that between the ulna and trochlea; and 2, that between radius and capitulum, such as is seen to be produced in the knee-joint by the ligamentum mucosum. Other situations in which fatty tissue exists are at the top of the olecranon, and in the bottom of the olecranon and coronoid fossæ.

The SYNOVIAL MEMBRANE being limited only by the attachment of the capsule, extends into the superior radio-ulnar joint, and lines the coronary or orbicular ligament.

ARTERIES.—A very free anastomosis takes place about this joint, between branches given off from the brachial above, and the anterior and posterior ulnar recurrent, the radial recurrent, and posterior interosseous recurrent below.

The brachial artery gives off the superior profunda to the posterior and outer sides, and a special branch from the lower third of its course to the forepart and outer side of the joint; while on the inner side, both in front and behind, there are branches from the anastomotica magna; and behind from the inferior profunda.

The Superior profunda, just as it is turning round the inner side of the humerus, sends a branch over the back of the triceps to the inner and back of part of the joint, where it anastomoses with the anastomotica magna and the posterior ulnar recurrent. While between the brachialis anticus and the triceps it gives off a large branch to the outer and back part of the joint, which anastomoses with the posterior interosseous recurrent. The artery forms an arch near the humeral attachment of the capsule with the anastomotica magna, and near the olecranon attachment of the capsule with the posterior ulnar recurrent. Some large twigs enter the capsule along the outer edge of the trochlea of the humerus; whilst in the groove of the humerus it gives off a branch which has been called "the posterior articular," which descends to the joint between the triceps muscle and the bone, and anastomoses with the other branches both on the inner and outer side of the olecranon fossa.

Branch direct from the Muscular Offsets of the Brachial.—From the outer side of the lower end of the brachial two vessels pass into the brachialis anticus, supplying it. The lower of these takes a deep course in a downward direction and gives off a long branch which descends in the middle line as far as the fatty tissue about the coronoid fossa and the capsule beyond;

it sends off numerous twigs as it descends, and anastomoses in front of the joint, on the inner side with the anterior branch of the anastomotica, on the outer side with the recurrent radial, and below, with the anterior ulnar recurrent.

The *inferior profunda* sometimes reaches the capsule on the inner side of the olecranon fossa, and ramifies upon it, between the inner condyloid process and the olecranon. It anastomoses with the posterior ulnar recurrent and the posterior branch of the anastomotica magna.

The Anastomotica magna, besides giving off non-articular branches to the pronator teres, brachialis anticus, and biceps, sends others to the capsule, and to the humerus within the capsule, which pass between the internal condyle and the projecting condyloid process. Another branch comes from that portion of the vessel which runs backwards through the intermuscular septum, and breaks up into twigs, which ramify over the condyloid process, enter the joint posteriorly, between the olecranon and inner condyle, and anastomose with the posterior ulnar recurrent. There is a perfect arterial crescent along the inner edge of the articular cartilage of the trochlea, formed between the anterior and posterior branches of this vessel; this sends filaments off from either side to ramify beneath the synovial membrane. Another branch passes beneath the brachialis anticus to the fatty tissue of the coronoid fossa, and anastomoses upon the front of the capsule with the deep articular branch from the lower end of the brachial.

Branches which ascend to the Joint from Vessels below it.—The Anterior ulnar recurrent reaches the capsule by sending branches both over and beneath the brachialis anticus. The branch which ascends upon the insertion of the brachialis runs under cover of the pronator teres, and ramifies on the inner side of the capsule and the humerus, between the condyloid process and the trochlea; it here anastomoses with the anastomotica magna. The deep branch passes beneath the border of the brachialis anticus to the coronoid process, which it supplies; it also ramifies over the annular ligament to the neck of the radius and the lower and outer part of the front of the capsule, where it anastomoses with the radial recurrent and the branch direct from the brachial.

The Posterior ulnar recurrent after giving off branches to the muscles under which it passes, and ascending beneath the flexor carpi ulnaris, and between its two heads of origin, sends several small twigs to ramify upon, and penetrate the capsule between the inner condyle and the olecranon; others extend over the back of the capsule beneath the tendon of the triceps, as far outwards as the external border of the great sigmoid fossa, where it anastomoses with the superior profunda and interosseous recurrent.

The Posterior interosseous recurrent passes upwards beneath and in the substance of the anconeus muscle to the interval between the olecranon and outer condyle; it helps to supply the corresponding part of the capsule and bones of the joint, as well as the back of the radio-ulnar articulation; and anastomoses with the superior profunda and posterior ulnar recurrent arteries.

The Radial recurrent sends branches to muscles, both upwards and downwards. Some of these ascend in and beneath the supinator brevis to the lower and outer part of the capsule; to the front and outer part of the annular ligament, and the bulging synovial membrane along its lower border; and likewise to the neck of the radius. It anastomoses with the terminal branches of the superior profunda, as well as with twigs of the posterior interosseous recurrent.

An arterial zone of considerable fineness surrounds the articular surfaces of the bones, close to the edge of the articular cartilage, either immediately beneath the synovial membrane, where it passes off from the capsule, in which case the vessels can be seen from the inner surface of the joint, or between the fibres of the capsule. On the humerus the anastomotica magna and superior profunda help to form the zone behind; and the anastomotica magna, recurrent radial, and direct branch of the brachial in front. On the ulna and radius, the anterior and posterior ulnar recurrent join the zone on the front and inner side of the elbow, as well as along the top of the olecranon; and the anterior ulnar recurrent also extends outwards to the radio-ulnar joint; the interosseous recurrent joins it on the outer side of the great sigmoid fossa, and upon the back of the neck of the radius; while the radial recurrent occupies the part of the neck of the radius between the interosseous recurrent behind and the anterior ulnar recurrent in front.

At the hour-glass contraction of the olecranon on each side, small twigs penetrate the bone, from the posterior ulnar recurrent on the inner, and from the posterior interosseous recurrent on the outer side.

NERVES.—The *musculo-cutaneous* supplies the chief of the branches to the elbow-joint. Small filaments are given off from it to the humerus and the elbow-joint in the arm. Like the circumflex nerve of the shoulder, the sub-occipital nerve, and many others, the musculo-cutaneous affords a good illustration of the associate distribution of the muscular, cutaneous, and articular branches of a single trunk; and furnishes an illustration of the truth of that law first pointed out and enforced by Mr. Hilton in his work on Rest and Pain, viz., that "the same trunks of nerves, the branches of which supply the groups of muscles moving any joint, furnish also a distribution of nerves to the skin over the same muscles and their insertions, and the interior of the joint moved by those muscles receives its nerves from the same source."

The *ulnar nerve* gives an articular branch as it lies in the space between the condyle of the humerus and the olecranon of the ulna.

The *median nerve*, either above the level of the elbow-joint or whilst beneath the pronator radii teres, generally gives a few filaments to the joint. They usually arise above the branches for the superficial muscles, except when the branch to the pronator teres arises above the joint.

The *musculo-spiral nerve* gives filaments to the back of the joint from an internal branch which supplies the short inferior fibres of the triceps; and others from the long slender branch to the anconeus, which takes the same course through the triceps muscle as the posterior articular branch from the superior profunda artery.

BURSÆ.—There are but three bursæ in immediate connexion with the parts of this joint; there is also a bursa between the tendon of the biceps and the tubercle of the radius.

1. On the outer aspect of the elbow, but more towards the front than the back of the limb, there is a small bursa between the tendon common to the extensor carpi radialis brevior and extensor communis digitorum on the one hand, and the capsule covering the rounded head of the radius on the other.

2. On the back of the capsule there is a bursa of varying size between the tendon of the triceps and that part of the

upper surface of the olecranon which is behind the attachment of the capsule of the elbow.

3. There is a large bursa mucosa in the subcutaneous areolar tissue over the olecranon, similar to that between the integument and the front of the patella and ligamentum patella at the knee.

4. The bursa between the forepart of the tubercle of the radius and the deep surface of the tendon of the biceps, just in front of its insertion, can scarcely be said to be in connexion with this joint.

THE MUSCLES.—The muscles in connexion with the elbow, like those in connexion with the knee, may be arranged into three sets: first, those which pass over and move the joint above the elbow as well as the elbow itself; secondly, those which pass over and move it alone, without reaching to the joint either above or below it; and thirdly, those which pass over and move the joints below the elbow as well as the elbow itself. There are, however, two important differences between the actions of the muscles of the upper and lower limbs; (*a*) in the forearm the movements between the radius and ulna are very free, and in consequence two of the muscles which flex the elbow also act upon the radio-ulnar joints; and (*b*) some of the muscles which act on the elbow and upon the wrist act also upon the digits. In the case of the lower limb there is no appreciable movement between the tibia and fibula, so that none of the muscles which move the knee can be said to have any distinct, still less any independent, action upon the joints between the two bones of the leg; and further, none of the flexors of the knee which pass over the ankle and extend that joint reach far enough to move any of the anterior tarsal joints, still less the joints of the digits.

The muscles which act on the shoulder and the elbow-joint are:—

1. The biceps in front; and 2, the long head of the triceps behind. The biceps is a flexor of the forearm, but besides acting on the shoulder and elbow-joint it acts also upon the radio-ulnar articulation, for if it be called into action when the hand is pronated its first effect is to produce supination of the forearm.

The triceps, by its long head, adducts the arm at the shoulder-joint in addition to its action on the elbow which it extends.

The muscles which act on the elbow, but do not extend to either the shoulder or wrist, are:—

1. The brachialis anticus; 2, the pronator radii teres; and 3, the supinator longus, in front. 4, The anconeus; 5, the two short heads of the triceps; and 6, the sub-anconeus, behind. The brachialis anticus is a simple flexor of the elbow. The pronator teres also acts on the radio-ulnar joints, but it flexes the elbow when pronation has been completed, or when it is prevented by opposing muscles.

The anconeus and the external and internal heads of the triceps are simple extensors.

The sub-anconeus being inserted into the capsule of the elbow, acts only to raise that structure during extension of the forearm.

The supinator longus extends along the outer and anterior part of the forearm, from the external condyloid ridge, to be inserted into the external border of the radius near the base of the styloid process. It acts principally as a flexor of the forearm, but this action on the elbow only takes place after flexion has been commenced by some other, *i.e.*, the more immediate flexor muscles. The action of this muscle upon the radio-ulnar joints is but slight, supination being principally effected by the biceps and supinator brevis; still, however, supination is partially accomplished by its contraction, especially when the forearm has been previously fully pronated.

The muscles which act upon the elbow and the wrist may be grouped into two sets:—

(*a*) Those which reach to their insertion into the palmar fascia, or into the carpus or the metacarpus only, but not to the phalanges; and which therefore, while they move the hand on the forearm, do not move the fingers.

1. The flexor carpi radialis; 2, the palmaris longus; and 3, the flexor carpi ulnaris, in front of the limb. 4, The extensor carpi radialis longior; 5, the extensor carpi radialis brevior; and 6, the extensor carpi ulnaris, behind.

The first three act chiefly as flexors of the wrist, but when this movement is either concluded or prevented they flex the elbow. They correspond with the gastrocnemius and plantaris in their action, which is exerted first on the foot and then to bend the knee.

The last three act primarily upon the wrist to extend it, but that action accomplished or prevented, they assist, the forearm being supinated, to extend the forearm at the elbow; the forearm being pronated, the radial extensors assist in bending the forearm.

(*b*) Those which reach to their insertion into the phalanges, and which therefore act not only on the elbow and wrist, but on the fingers. In the lower limb there are no muscles which, arising above the knee, are inserted so far down upon the extremity as to be able to move the toes. The muscles which move the toes arise either from the leg bones, and pass over the ankle, or from the foot. The muscles which move the fingers arise either from the hand; or from the forearm, and thus move the wrist as well; or from the condyles of the humerus, and thus move both fingers, wrist, and forearm. One effect of this variety of origin is that the movements of the fingers can be brought into immediate muscular association with those of the wrist and elbow; a necessity, owing to the frequency with which these several joints are required to be moved at the same moment. In the case of the foot, the toes take but little share in the uses of the lower limb, and, except to give a last impulse to the spring in jumping, in standing on tiptoe, and in some of the movements of the opera dancer, they are seldom of any special use; and even in these uses, though the flexors of the toes are associated with flexion (properly described), of the ankle, the knees are fixed with the legs extended. These muscles are :—

1. The flexor sublimis digitorum, in front. 2, The extensor communis digitorum; and 3, the extensor minimi digiti, behind.

The flexor sublimis acts chiefly to bend the second phalanges, and when this action is either completed or opposed, to bend the wrist; when again this action is completed or opposed, it assists in bending the elbow, as when the open hand is pressed against a box or heavy weight which is being drawn towards the body by flexing the elbow. This action would be of course also assisted by the flexors of the wrist.

Conversely, the extensor muscles act first upon the phalanges to extend the fingers, then upon the wrist, and lastly they may assist in extending the elbow, as when we give a backhanded blow with the closed fist, the wrist being tightly set.

In this action they would be assisted of course by the extensors of the wrist.

Thus if we group the muscles which are in connexion with the elbow into flexors and extensors, we see at once that the following muscles can all take part in the most powerful efforts at flexion:—The brachialis anticus and biceps, the one inserted into the base of the coronoid process and the top of the shaft of the ulna, and the other into the tubercle of the radius, so that both bones are acted upon by these the most immediate flexors; the pronator teres, the supinator longus, the flexors of the wrist, the palmaris longus, and the flexor sublimis digitorum. The radial extensors flex the pronated forearm.

The following muscles can all assist in the most complete efforts at extension:—The anconeus and the triceps, both inserted into the ulna; the two radial extensors (the forearm being supinated) and the ulnar extensor of the wrist; the common extensor of the digits, and the extensor of the little finger.

The Movements of the Elbow.—The elbow is a true hinge joint, and, as such, flexion and extension are the only movements which can take place at it. These movements are oblique, so that the forearm is inclined inwards in flexion, and outwards in extension. They are limited by the contact respectively of the coronoid and olecranon processes of the ulna, with their corresponding fossæ in the humerus. The extent of these hinge-like movements is determined by the relative proportion between the length of the processes of the ulna and the depth of the fossæ which receive them. The ligaments in front of and behind the joint, with certain portions of the lateral ligaments, are put on stretch during extension and flexion; but though they assist in checking the velocity and force of the movements before the limits of those movements is attained, and therefore in preventing any undue violence of contact of the bony processes with the lamina separating the fossa on the front from that on the back of the humerus, they do not control or determine the extent of flexion and extension. The limit of extension is not reached until the ulna is nearly in a straight line with the humerus, and the limit of flexion not until the forearm makes with the humerus an angle varying between something less than 30° and something over 40°. This variation does not depend upon the bulk of the soft parts covering the joint, but, as just said, upon the proportion which the length of the olecranon and coronoid processes bear to the depth of the olecranon and coronoid fossæ. This can be proved by measuring with the same goniometer the angle of flexion at the elbow in the living subject, and in the dead in various stages of dissection. Thus I have found, while some living elbows cannot be flexed to a more acute angle than 35° or 40°; others, dissected cleanly to the capsular ligament, could only attain to 42° or 43°; while another again, with the skin and fasciæ removed, and the muscles dissected cleanly, but not removed, could be brought to an angle of a little less than 30°.

While the articulation between the radius and humerus allows of the radius rotating upon the humerus in supination and pronation, and accompanying the ulna in its motions of flexion and extension, it gives no security to the elbow-joint, and adds nothing to the hinge-like arrangement of the humero-ulnar portion of it, at which the movements take place. The plane in which the movements occur is a nearly vertical one, with a slight obliquity inwards of about 10° from the axis of the shaft of the humerus; and the transverse axis round which the ulna revolves corresponds to a line through the lower and forepart of the outer condyle, and through a ridge which runs upwards and backwards from the inner side of the trochlea to the lower part of the internal condyle. The obliquity of the plane of movement is occasioned by the greater prominence of the inner lip of the trochlea below, and by the eversion or outward inclination of the upper and back part of the trochlea. A consequence of this obliquity is that the ulna and radius have a slightly outward inclination from the axis of the humerus, which is most marked in extension of the elbow, though it is observable in slightly flexed positions of the joint. In spite of this, however, and even as a result of the obliquity of the plane of motion, the hand in flexion is carried towards the middle third of the clavicle, instead of being directed vertically to the acromion overhanging the shoulder-joint; but any greater inclination of the forearm towards the median line of the body, as in buttoning a waistcoat or bringing the hand to the face, is caused by rotation of the humerus at the shoulder, and not by anything in the construction of the elbow.

The inward direction of the shaft of the humerus, the backward inclination of the head of that bone, together with the inward obliquity of the forepart of the elbow-joint, and the great freedom and facility of pronation, all assist in bringing the hand, when in use, towards the middle line, so that, as it were, they might be under the immediate observation of their owner; or, in other words, that the eyes may see what the fingers are about. This is just the reverse of what we find in the lower extremity, when the direction of the head and neck and the inclination of the shaft of the femur, the rotation of the knee and the construction of the ankle, are all subservient to the outward turning of the foot, whereby in walking or running any awkwardness of movement or injury to the opposite foot is prevented.

In flexion and extension, the cup-like depression of the head of the radius moves upon the capitulum of the humerus, and the inner margin of that depression upon the groove between the capitulum and the trochlea.

In full extension and supination, the head of the radius is barely in contact with the inferior surface of the capitulum, but projects so much backwards that its posterior margin can be felt as a prominence at the back of the elbow, and the tip of a knife-blade can be introduced, flat, between the articular surfaces of the two bones. In full flexion the anterior margin of the head of the radius is received into and checked against the depression above the capitulum. In mid-flexion the cup-like depression fairly receives upon it the capitulum, and the radius being more completely steadied by the humerus in this position than in any other, pronation and supination take place most perfectly.

Though in the extended position of the limb the hand by pronation can make a more complete sweep round than in any other, yet this movement is not all true pronation, but is in large part due to the rotation of the humerus at the shoulder.

There is nothing in the shape of the radius or humerus which prevents the radius completely revolving round its axis, as is shown by dividing all the structures which attach the radius to the ulna, except the orbicular ligament, and then just loosening the capsule of the elbow from the neck of the radius. This done, the radius can be turned round and round on the capitulum, like a spindle in its bush. In the undissected state, this rotation is checked by the middle and inferior radio-ulnar connexions.

It has been stated above, that the elbow is a true and typical hinge joint, but anatomists have been divided in opinion as to the possibility of any lateral movement at the elbow. Monro and Bichat assert that this movement is possible in the semiflexed state of the elbow, when the lateral ligaments are least tense, and they consider that it consists in a slight degree of rolling of the middle prominent part of the greater sigmoid cavity of the ulna in the trochlea of the humerus. Probably this movement is produced by the lowest, and therefore nearly horizontal fibres of the triceps, on each side of the olecranon, and by the anconeus muscle.

As a means of expressing passions and feelings, the movements of the elbow are frequently employed in elocution to assist the voice and the facial muscles. In this relation it will be found, I think, as a general rule, that flexion and extension at the elbow generally indicate feelings of a quick, passionate, and decided character, and are not employed, like the various movements of the shoulder, to suggest or emphasise any transcendent, deep, or tender feelings. The movements of the elbow for the purposes of expression are often associated with the flexion or closure of the fingers; whereas those of the shoulder are most frequently employed with wrist movements, and, sometimes together with those of the wrist, with others of the index-finger also.

Thus, in resolutely striking with the closed fist upon the table; in hastily brushing away a tear which is unacceptably stealing upon the cheek; in tearing at the hair in rage; in attitudes of mental agony, such as that assumed by the actor, when as Othello he says, with linked fingers and uplifted hands—" Not a jot, not a jot! Blood, Iago, blood! But oh, the pity of it, Iago!—the pity of it;" and in such like moods, the elbow and the fingers work together. In the attitude of the suppliant; in giving expression to feelings of complacent triumph, such as are implied in the opening speech of " Richard III.,"—

> "Now is the winter of our discontent
> Made glorious summer by this sun of York;"

when, with the upraised and extended arm, a graceful curl of the wrist, the actor with a rich, deep, thrilling note upon "buried," indicates how the clouds which lowered round his head, were "in the deep bosom of the ocean bury'd:" so in the rhapsody of boundless passion, as when, in "Romeo and Juliet," Juliet, in solemn attestation of her love for Romeo, says (with arms upraised and hands drooping at the wrist),

> "When he shall die,
> Take him and cut him out in little stars,
> And he will make the face of heaven so fine
> That all the world will be in love with night,
> And pay no worship to the garish sun."

In these and such-like mental states the shoulder combines with the wrist for the purpose of appropriately suiting the action to the word.

Sometimes, too, in giving a command, the shoulder and wrist with the extended index-finger, produce a marked effect, such as accompanies the word "Begone!" but in such cases the elbow takes the initiative, as the hand, with most of the fingers nearly closed, is first brought across the chest to the opposite shoulder, to give point and decision; while the fully extended limb is afterwards thrown forwards by a movement at the shoulder, to give dignity or impressiveness to the injunction.

The movements of the elbow and fingers are employed in anger or defiance when the fist is shaken and the elbow bent. In the calmness of bestowing benediction, the arm is raised at the shoulder and the fingers outstretched, so that the open palm can be placed upon the recipient's head. In the bitterness of shame the face is covered by the hands, while we bend the elbows, and involuntarily attempt to close the fingers upon the palms as they lie pressed against the forehead. In the agony of grief we bend the elbows and wring the locked fingers; while, on the contrary, in the abandonment of despair we throw our open hands and arms above our heads.

The movement of supination is one indicative of disgust, impotence, and annoyance, as when the palms are turned quickly forwards or upwards, as if to say we "will have none of it;" or "I wash my hands of the whole affair."

That of pronation is suggestive both of power and determination, as well as of repose and resignation, as when striking the table with the open palm, and in letting the forearm drop helpless by one's side.

Complete pronation is a position of the greatest elegance and grace, and is the one most agreeable to the eye as well as to the feelings. Tennyson knew this when he described Vivien (trying to arouse the impassioned Merlin) thus :—

> "Curved an arm about his neck,
> Clung like a snake; and *letting her left hand*
> *Droop* from his mighty shoulder, as a leaf,
> *Made with her right a comb* of pearl to part
> The lists of such a beard as youth gone out
> Had left in ashes."

Were this the proper place, and space permitted, instances might be multiplied to show how frequently the movements of the upper limbs are employed as a means of expressing feelings and emotions; and much might be said in support of the opinion, that a considerable amount of constancy exists in the association of movements of the shoulder with those of the wrist; and of the elbow with those of the fingers.

In movements *from* the body expressive of command or repulsion; in expanding gestures suitable to feelings of liberality, acquiescence, candour, and distribution; in rising motions which express suspension, climax, or appeal, as well as in falling motions which suggest completion, declaration, or resignation; and in broad and sweeping gestures which illustrate a general statement, or imply boldness, freedom, and power, the shoulder and the wrist-joints move together, or the wrist a little later than the shoulder, the fingers meanwhile, in most cases, being kept extended.

In movements *towards* the body, which indicate self-esteem or egotism; in the contracting gestures which imply frugality or reserve, obeisance, and mock humility, or which express doubt, meditation, or listening; in the sudden movement of decision or discovery, harshness or temerity, the elbow and fingers move simultaneously, the fingers sometimes being tightly clenched into a fist, at others slowly contracting downwards upon the palm, or slowly or forcibly extended from it.

CHAPTER XIII.

THE UNION OF THE RADIUS WITH THE ULNA.
THE RADIO-ULNAR ARTICULATIONS.

THE radius is firmly bound to the ulna by two articulations, one at each extremity; and by two intermediate ligaments between their shafts.

In the superior radio-ulnar joint the ulna receives the head of the radius upon a small cavity on the outer side of its upper end, and the articular surfaces are so related to one another that the ulna somewhat underhangs the radius; in the inferior radio-ulnar joint, on the contrary, the radius receives the rounded inferior extremity, or head of the ulna, upon a lateral cavity on its inner side, which underhangs the end of the ulna. Thus the ulna, which is more widely connected with the humerus than the radius, supports that bone against forces which drag the forearm from the arm; and at the same time receives from the radius part of the forces transmitted from the wrist.

In the superior radio-ulnar joint the round head of the radius rotates round its own axis in the lesser sigmoid socket of the ulna; in the inferior radio-ulnar joint, the radius revolves upon the rounded end of the ulna (and its facet is concave in adaptation to this movement) around an axis which corresponds to a line drawn through the head of the radius, the lower end of the ulna, and the metacarpal bone of the ring-finger.

The Superior Radio-ulnar Articulation.

Class, Diarthrosis. *Subdivision*, Trochoides.

The bones entering into this joint are the lesser sigmoid notch of the ulna, and the smooth vertical surface of the head of the radius.

ULNA.—The lesser sigmoid cavity of the ulna is situated at the top of the outer side of the shaft of the ulna, and is therefore at right angles to, and continuous over a sharp articular edge with, the great sigmoid cavity. It faces directly outwards, is crescentic in outline, measures one inch from before backwards, and three-eighths of an inch from above downwards. It forms about one-fourth of a circle, which is completed by the orbicular ligament. The anterior edge is prominent, projects outwards, and is formed by the outer border of the coronoid process. The posterior edge is also prominent, and separates the fossa from the excavated posterior surface of the shaft for the anconeus muscle. The lower border is also prominent and well-defined, and separates the sigmoid cavity from the depression for the supinator brevis muscle. As the cavity is inclined a little obliquely outwards at its lower end, especially towards the front, it somewhat underhangs the head of the radius; but this only to a slight extent.

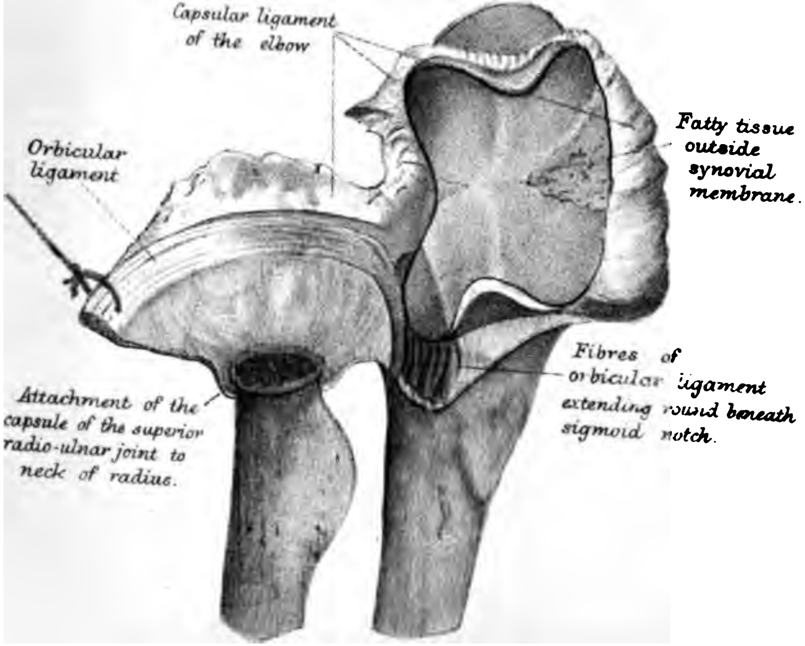
RADIUS.—The articular portion of the head of the radius which enters into this joint is the smooth rim or vertical border which extends completely all around the bone. It is about three inches in circumference. At some parts it is not more than one-fifth of an inch deep; but on the inner side, where it is in contact with the ulnar cavity, it is usually about three-eighths and sometimes one-half of an inch in depth. Below this surface the bone is constricted into a slender neck, which is usually less than two inches in circumference.

THE LIGAMENTS.—There is but one ligament proper to this articulation—viz., the coronary or annular; but the anterior, posterior, and external portions of the capsule of the elbow are connected with, tighten, and strengthen this one ligament, and help to enclose the joint, which it must be understood is continuous with the elbow-joint itself. Moreover, some thin fibrous bundles pass from the lower edge of the coronary ligament, and the ulna below the lesser sigmoid cavity, to the neck of the radius and cover in the joint below.

The coronary ligament consists of bands of strong fibres, somewhat thicker than the capsule of the elbow-joint, which pass circularly around the head of the radius, retaining it against the side of the ulna. The bulk of these fibres forms about three-fourths of a circle, and together with the lesser sigmoid cavity completes a collar for the head of the radius to rotate within; but some of the lowermost fibres are continued round below the sigmoid cavity so as to form a

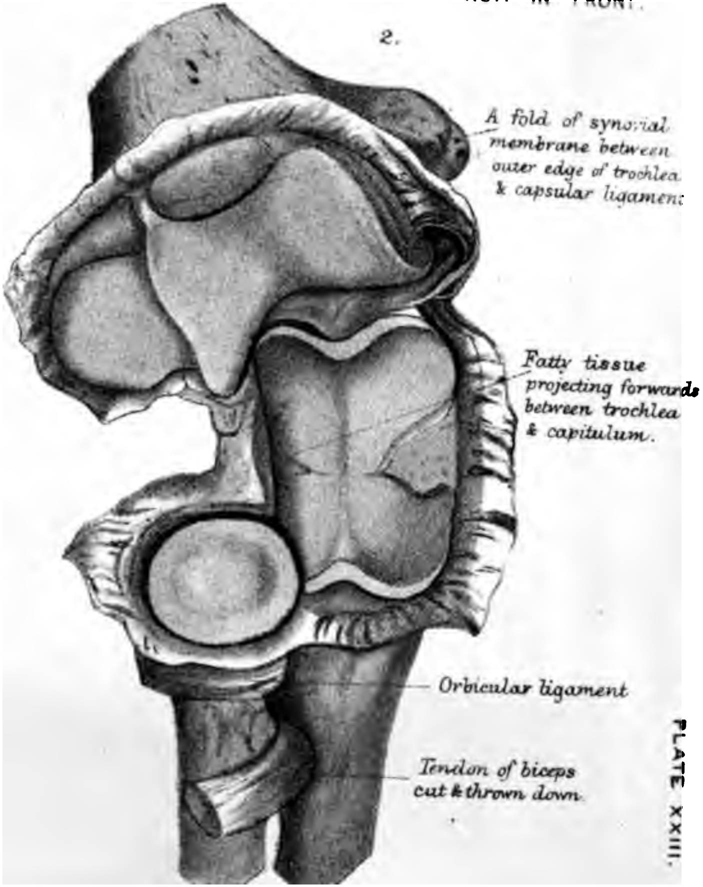
ORBICULAR LIGAMENT DIVIDED & DRAWN OPEN. HEAD OF RADIUS REMOVED.

1


Capsular ligament of the elbow
Orbicular ligament
Fatty tissue outside synovial membrane.
Fibres of orbicular ligament extending round beneath sigmoid notch.
Attachment of the capsule of the superior radio-ulnar joint to neck of radius.

SHOWING ATTACHMENT OF CAPSULE OF ELBOW ALL AROUND. AFTER LAYING JOINT OPEN FROM IN FRONT.

2.


A fold of synovial membrane between outer edge of trochlea & capsular ligament
Fatty tissue projecting forwards between trochlea & capitulum.
Orbicular ligament
Tendon of biceps cut & thrown down

THE ELBOW JOINT.

A. Horsman del. ad. nat.

PLATE XXIII.

complete circle of ligamentous fibres. Thus the ligament encircles the whole of the articular edge of the head of the radius, except that part of it which occupies the lesser sigmoid cavity of the ulna.

The ligament is inseparably connected along its upper edge and external, *i.e.*, non-articular surface, with the external, anterior, and posterior segments of the capsule. Some few of these fibres, especially of the external segment, pass downwards to be attached to the neck of the radius; but the lower part of the articulation is covered in by a thin, independent layer of felt-like membranous fibres which pass down from the lower edge of the coronary ligament to the neck of the radius, where they are connected loosely enough to allow of the head and neck of the bone rotating around its own axis. These fibres are the only portion of the ligaments at the elbow and superior radio-ulnar joints, which serve to check the rotation of the radius in pronation and supination.

The fibres of the orbicular ligament (all but the lowest, which pass quite around below the sigmoid fossa) are fixed to the anterior and posterior margins of the lesser sigmoid cavity of the ulna, and to the ridges of bone extending downwards from them; behind, by means of a strong fibrous expansion to the rough ridge which separates the surface on the shaft for the anconeus, from that for the supinator brevis; and in front, to the oblique ridge which descends along the inner side of the coronoid process.

The SYNOVIAL MEMBRANE of this joint is one with that of the elbow, and a prolongation forwards of the fatty tissue at the back of the elbow-joint projects into the angle between the head of the radius and the back of the lesser sigmoid cavity; often too there are little fringes of synovial membrane containing fat attached along the edge of the coronary ligament. The membrane, after lining the inner surface of the coronary ligament, passes upon the fibrous tissue between its lower edge and the neck of the radius, and is thence reflected upwards on the neck of the bone to the articular cartilage with which it is continuous, and with which it can be peeled off. Thus, like the necks of the femur and of the humerus, the non-articular neck of the radius is invested by synovial membrane, and a few fibres are reflected upon it from the ligamentous tissue which surrounds it.

THE ARTERIES.—Being part of the elbow-joint, this articulation gets its blood supply from the vessels which ramify upon the outer side of the elbow in front and behind.

They are the superior profunda, interosseous recurrent, radial recurrent, and anterior ulnar recurrent.

1. The superior profunda artery gives off branches which descend to anastomose with the posterior interosseous recurrent, and to penetrate the joint close to the back of the lesser sigmoid cavity.

2. The interosseous recurrent reaches the joint by passing upwards in the substance of the anconeus muscle to the interval between the olecranon and outer condyle, where it sends twigs into the bones and others through the capsule into the joint. It supplies the back of the radio-ulnar articulation and anastomoses with the superior profunda branches.

3. The radial recurrent sends branches which ascend in and beneath the supinator brevis to the front and outer part of the annular ligament and the loose baggy synovial membrane along its lower border, as well as to the neck of the radius.

4. The anterior ulnar recurrent sends a deep branch beneath the border of the brachialis anticus to the neck of the radius, the front of the annular ligament, and the lower and outer part of the capsular fibres, amongst which it anastomoses with the radial recurrent.

THE NERVES.—This joint, from being so entirely a part of the elbow, must share with it the influence of the nerves which supply it.

The *interosseous division of the musculo-spiral*, whilst in the substance of the supinator brevis muscle, gives small filaments to the lower part of the superior radio-ulnar articulation.

THE MUSCLES.—The muscles which pass over this joint are the following:—

The supinator longus, extensor carpi radialis longior and brevior, on the outer side; the anconeus, immediately in contact with it behind; and below and external to the anconeus, the extensor carpi ulnaris and extensor communis digitorum, each of which is separated from the joint by the supinator brevis. The supinator brevis closely surrounds the annular ligament, and the capsular fibres below that ligament, and is indeed attached to both.

The biceps tendon passes over the fore and inner part, and the brachialis anticus spreads out laterally over the inner and front part.

The pronator radii teres crosses obliquely at the lower and front part of the joint.

Of these muscles, which from their situation are in connexion with the joint, those which act upon it most directly, are the supinator longus, the supinator brevis, the pronator radii teres, and the biceps. There are two other muscles at least which effect movements at this joint, though they are situated at a distance from it—viz., the pronator quadratus and the flexor carpi radialis; the latter muscle contributes slightly to pronate the forearm. There can be little doubt that the extensors of the fingers, which arise from the outer condyle of the humerus, and pass obliquely to the back of the lower end of the radius, where they are retained in their direct course by the posterior annular ligament, assist the action of pronation when the fingers are kept rigidly extended, as in the last movement of the hands in swimming. Certainly the extensor carpi radialis longior and brevior, when the hand is turned back to the greatest degree, pronate it.

The *chief pronators* are the radii teres and the quadratus, one of which is a pronator pure and simple, and acts upon the radius at its lower extremity—viz., the pronator quadratus; while the other, acting upon the radius at its centre, though a powerful muscle in pronating the forearm, acts also to assist in bending the elbow when pronation is either completed or prevented.

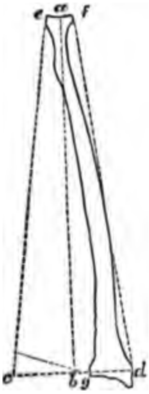
The biceps, when acting upon the pronated forearm, first acts to *supinate* the radius, and this is indeed one of its chief uses. How strongly it acts in this way may be tested by feeling the degree of firmness of the belly of the biceps, first when the elbow is flexed with the forearm pronated, and next when it is flexed with the forearm supinated. The muscle is much harder in the latter case, because its fibres are then more tightly contracted.

Of the *other supinators*, one acts immediately upon the radius, as a supinator pure and simple; it is the supinator brevis, and by it supination is principally effected. The other, the supinator longus, is principally of use in flexing the elbow, and only secondarily supinates the radius by acting upon it at its lower end.

The extensor ossis metacarpi pollicis, and extensor secundi internodii pollicis, from their oblique direction over the wrist, must assist in supination.

THE MOVEMENTS.—The radius rotates around the axis through its own head and neck, within the collar formed by the lesser sigmoid cavity of the ulna and the coronary ligament. This rotation is called *pronation* when the radius from a position parallel, or nearly so, to the ulna turns inwards so that it crosses the ulna obliquely; and *supination* when it turns back again from within outwards, so as to uncross as it were the ulna and become again nearly parallel to it. In pronation and supination, the radius carries with it the hand, and communicates to it the movements popularly attributed to the wrist. Thus, in pronation, the hand is carried over so as to face backwards, as in holding the hand to receive anything from behind; or downwards, as in the act of writing or playing the piano; whereas, in supination, the hand is facing forwards, as in throwing an underhand ball at a wicket; or upwards, as in tossing a coin in the open hand. In these movements of the radius, the hand is made to rotate around an axis drawn through it a little to the inner side of its middle line. It has occurred to Mr. Ward to enunciate the following general formula to express the relation of the two extremities of the radius in pronation and supination:—"The head of the radius is so disposed in relation to the sigmoid cavity of the lower extremity, that the axis of the former, if prolonged downwards, falls upon the centre of the circle, of which the latter is a segment." Thus the real axis round which pronation and supination occur is one corresponding to the axis of the head and neck of the radius, but which leaves the radius just below the bicipital tuberosity, crosses the interosseous membrane or interval between the bones, and passes through the inferior extremity of the ulna, and onwards to the tip of the ring-finger. The real axis of rotation is the line, *a b*, in the accompanying diagram: *e f* represent the apex, and *c d* the base of a blunt-topped cone. The centre of the apex corresponds with the centre of the head of the radius, and the centre of the base with the centre of the circle, of which the sigmoid cavity of the radius is a segment—*i.e.*, with the centre of the head of the ulna. The axis of the cone corre-

DIAGRAM IV.



sponds with the axis of the head of the radius. It is around the lower part of this axis that the hand rotates when moving with the radius, and if the radius rotated around any other axis than the one described, some slight hinge-joint movement would take place at the superior radio-ulnar articulation, which is not the case. Associated with this rotation, however, in the ordinary way, there is some rotation of the humero-ulnar shaft, which causes a lateral shifting of the forearm and hand from side to side; thus with pronation there is some abduction, and with supination some adduction combined, so that the hand may be able to keep on the same superficies in both pronation and supination.

Pronation and supination can scarcely be said to be in any way checked by any of the structures concerned in the superior radio-ulnar articulation. Only one portion of the ligaments about the elbow could possibly have any effect whatever in controlling the rotation of the radius; this is the membranous felt-like ligamentous tissue which passes from the lower edge of the annular ligament on to the neck of the radius, and the few fibres of the capsule of the elbow-joint which are inserted into the radius. But these structures can usually be detached from the bone by a few forcible rotations; and this done, the radius, if free of all muscles and all ligaments below the elbow, can be turned round and round within its osteo-ligamentous collar like a spindle in its bush. *In supination* the oblique ligament and the lowest portion of the interosseous membrane are put on stretch, and with the internal lateral ligament of the wrist, are the chief obstacles to over-supination. The upper and middle portions of the interosseous ligament are relaxed by supination. *In pronation*, the lower and middle portions of the interosseous ligament are on stretch, and the oblique ligaments slackened.

As will be mentioned in the description of the inferior radio-ulnar joint, the posterior ligament of that articulation tends to check pronation, the anterior ligament supination. The internal lateral ligament of the wrist helps to limit each movement, but especially supination. Further, the muscles, more especially the pronators, offer some check to over-supination, and the supinator brevis to over-pronation.

The convex capitulum of the humerus when the radius is in contact with it—*i.e.*, in the semi- and completely flexed positions—steadies the head of the radius in its movements, and tends to define more precisely the axis of rotation of the upper end of the bone.

Both in the structure and the resulting movements there are many analogies and similarities between the articulation of the odontoid process of the axis and the anterior part of the ring of the atlas on the one hand, and the head of the radius and osteo-ligamentous ring of the ulna on the other.

Free supination is only found in those animals who use their fore-limbs for prehensile purposes; and in proportion as the fore-limb is more needed for support, the bones of the forearm are less adapted for rotation. In the carnivorous, ruminant, pachydermatous and many other animals, the radius extends a long way across the articular facet of the humerus, so that it is always in a state of pronation; but in the quadrumanous and some other animals, *e.g.*, sloth and seal, as well as in man, the head of the radius is confined to the outer condyle of the humerus, and supination becomes possible. In no animal is the movement so free as in man. The power of supination in man is greater than that of pronation, owing to immense leverage and great power obtained by the attachment of the biceps to the tubercle and inward curve of the radius. For this reason, the tools of workmen are so made that screw-driving, gimlet-turning, and other mechanical work of this kind, is done by supination of the right hand. It should be pointed out, however, that the pronator teres obtains all the advantage it can by its insertion into the most convex point on the outer side of the lower curve of the radius, just as the biceps does from its insertion into the most prominent point of the convexity of the upper curve.

The Union between the Shafts of the Radius and Ulna.

THE RADIO-ULNAR INTEROSSEOUS LIGAMENTS.—Two ligaments extend between the bones of the forearm; one, a short narrow fibrous band, passes obliquely downwards and outwards from the ulna to the radius, and is called the oblique ligament; the other occupies the greater part of the interval as far down as the inferior radio-ulnar articulation, and its fibres chiefly pass downwards and inwards to the ulna.

1. The *oblique ligament* is a narrow but usually a strong

band, but not unfrequently removed in dissecting. It is connected above to the lower part of the rough outer ridge of the coronoid process, and to the upper end of the line descending from that process to the outer edge of the shaft; and below, to the lower end of the posterior edge of the tubercle of the radius, and to the irregular vertical ridge descending from it to the inner edge of the bone. Unless care be used it is easy to detach this ligament from the ulna with the tendon of the brachialis anticus, or with the flexor profundus digitorum, or from the radius with the tendon of the biceps; indeed the fibres of the ligament run into, and blend with those of the biceps tendon. Behind, especially at the ulna, the supinator brevis is in close relationship with this ligament; and below, a thin membraniform tissue passes off from it to the upper edge of the interosseous ligament, and through the space thus occupied the posterior interosseous vein and artery pass backwards.

2. The *interosseous ligament or membrane* is attached to the ulna at the lowest part of the ridge in front of the depression for the supinator brevis, which passes downwards from the base of the coronoid process to the outer edge of the shaft; then along the whole length of this sharp edge as far as the pronator quadratus; thence along the rounded border, which gradually approaches nearer to the fore than back surface of the bone, as far as the inferior radio-ulnar articulation. To the radius it is attached along the inner edge of the bone from an inch below the tubercle to the sigmoid notch for the ulna. It is strongest in the centre, where its fibres are very dense and closely packed; it is also well-marked beneath the pronator quadratus muscle; and quite at the lower end it thickens considerably, forming a strong bond of union between the upper margin of the sigmoid cavity and the rounded head of the ulna, and some of its fibres are prolonged over the head of the ulna to be attached beyond the margin of its articular surface both on the front and back aspects, though more especially over the front.

The direction of the fibres of this ligament is chiefly inwards and downwards from radius to ulna; but some fibres pass in the opposite direction, and others are transverse, especially at the lower end. Still it is quite true that the ligament is composed chiefly of fibres whose direction is from radius to ulna, and this is most declared where the ligament is strongest—viz., in the centre. On the posterior surface of the membrane one or two linear bands of fibres, well marked, are often found to pass obliquely downwards and outwards from ulna to radius; and very frequently there is a very strong bundle as large as the oblique ligament, and which may be called the *inferior oblique ligament,* on the posterior surface of the membrane, which extends from the ulna an inch and a half above its rounded extremity to the prominent ridge above and behind the sigmoid notch of the radius. The upper edge of the interosseous membrane is concave, and connected with the oblique ligament above by a thin membraniform structure, pierced by the posterior interosseous artery. At its attachment to the radius and ulna the ligament is blended with the periosteum.

ARTERIES.—Throughout it is very vascular, being well supplied with blood by the anterior interosseous artery. This artery gives numerous branches to it, some of which penetrate it and supply the deep extensors; others ramify in the substance of the ligament. Below, the artery pierces the ligament about an inch and a quarter from its lower end, sometimes running in between its layers, and after giving off the communicating branch to the posterior interosseous artery, returns to descend to the inferior radio-ulnar joint upon the front surface of the membrane.

NERVES.—The interosseous branch of the median nerve accompanies the anterior interosseous artery, and descends with it upon the front surface of the interosseous membrane, and supplies filaments to it.

THE MUSCLES.—The muscles in connexion with the interosseous membrane of the forearm are the following:—

In Front.—The flexor profundus digitorum, from the ulna half, for three-fourths the length of the membrane.

The flexor longus pollicis, from the part adjacent to the radius between the oblique line above and the edge of the pronator quadratus below.

The pronator quadratus, at the lower two inches of its extent.

Behind.—The supinator radii teres, in the upper third. This muscle separates the anconeus and some of the extensors of the wrist and fingers from the membrane.

The extensor ossis metacarpi pollicis, from the whole width of the membrane a little above the middle of the forearm.

The extensor primi internodii pollicis, from the interosseous membrane near the middle of the forearm.

The extensor secundi internodii pollicis, from about an inch of the membrane at its lower end.

The extensor indicis passes obliquely over it at quite its lower end, but is not usually attached to it.

Influence on Movements.—The use of these ligaments is to bind the shafts of the bones together, and thus to increase the security of the radio-ulnar joints. The *oblique ligament* acts as a stay or support to the radius at a point rendered weak by the meeting of two curves in that bone—viz., one with convexity inwards at the tubercle for the biceps insertion; and the other with convexity outwards for the pronator radii teres insertion. These curves give great leverage and advantage to their respective muscles, each of which is inserted into the most convex part of the curve; and the oblique ligament gives strength to what is otherwise a weak point in the shaft. This oblique ligament and the inferior oblique ligament, above described, when present, assist in checking supination. They are put on stretch during this movement, the superior one by the eversion of the tubercle of the radius from the coronoid process, and the inferior by its winding round the lower end of the ulna. But the chief influence in checking supination is not to be found in ligament at all, but in the contact of the posterior edge of the sigmoid cavity of the radius with the tendon of the extensor carpi ulnaris, as it lies in the groove between the styloid process and the round head of the ulna. From their direction, too, the oblique and the inferior oblique ligaments are able to resist any forces which tend to pull the radius with the hand from the humerus. The ulna is much more firmly bound to the humerus than the radius, whilst it is but slightly connected with the hand, and any forces acting on the hand tending to drag the forearm from the arm would strain unduly the annular ligament were it not for these ligaments, and for the transverse fibres of the interosseous membrane.

The *interosseous membrane* exerts but very little influence in checking movements; none at all over supination, except by its lowest oblique fibres. Its lower fibres, and to a less degree its middle fibres also, have some effect in checking pronation. Pronation is also checked partly by the posterior inferior radio-ulnar ligament, but perhaps chiefly by the contact of the soft parts as the radius rolls forwards and inwards, so as to cross obliquely over the front of the ulna.

I have always been in the habit of teaching that one of the chief uses of this membrane, and of the very definite inward and downward direction of the bulk of its fibres, is for the purpose of transmitting the weight of the body from the ulna to the radius in the extended position of the elbow; as, for instance, in pushing forwards with outstretched arms, or in crawling on "all fours," or in stooping from the erect posture, and bearing down upon a table. In these positions the ulna is little or not at all in contact with the carpus, but forms the chief connexion at the elbow; and the radius is but slightly in contact with the large articular surface of the humerus, but forms the chief connexion of the forearm at the wrist. When then weight or other forces pass from the humerus to the head of the ulna, this bone is pressed downwards towards the wrist; but at the same time, for the same reason and to a proportionate degree, the ulna drags on the interosseous membrane, which, owing to the direction of the fibres, becomes tighter and tighter as the force increases; not looser and looser, as would be the case if the fibres passed in the opposite direction, as do those of the oblique ligaments. Thus the membrane tends to pull the radius more firmly against the carpus; and thus the weight passes on into the hand, and so to the supporting surface. Or, conversely, the pressure communicated from the hand to the radius forces up the radius against the capitellum, but at the same time slings the ulna, and drags it up more forcibly against the trochlea of the humerus. By this arrangement the violence of a fall upon the hand is broken, for were it not for these fibres of the interosseous membrane the whole of the impulse would be communicated directly through the head of the radius to the capitellum.

Another and an important use of the interosseous membrane is to give origin to the various muscles in connexion with it on the front and back of the forearm.

The Inferior Radio-ulnar Joint.

Class, Diarthrosis. *Subdivision*, Lateral Ginglymus.

The inferior radio-ulnar articulation is in one respect the reverse of the superior, for the radius, instead of presenting a circular head to rotate upon a concave facet of the ulna, has a concave facet which rolls upon the rounded lower end of the ulna. In several respects it differs widely from the superior joint. 1.

In the superior, the head of the radius rotates round its own axis; in the inferior, the radius turns in the arc of a circle, whose centre is the fossa between the styloid process and the articular surface of the ulna—*i.e.*, the point at which the fibro-cartilage is attached. 2. In the superior, the most important structure is the annular ligament within which the head of the radius rotates; in the inferior, the most important structure is a fibro-cartilage, which acts as a flexible or movable spoke to hold the radius against the ulna as it rotates in the arc of a circle. 3. The superior joint is in communication with the elbow; the inferior has usually no connexion with the wrist-joint, and when it has, it is only by means of an imperfection in the fibro-cartilage. 4. The radius forms but an insignificant part of the construction of the elbow-joint, the ulna but an insignificant part of the wrist; but whilst the terminal facet of the head of the radius articulates with the capitellum of the humerus, the terminal facet on the head of the ulna articulates with the fibro-cartilage which shuts it off from any direct contact with the carpus.

The constituent parts of the joint are—the lower ends of the radius and ulna, the fibro-cartilage, and the ligaments which assist in forming an imperfect capsule, together with a synovial membrane. The articulation may be said to consist of two parts at right angles to one another—viz., *one* between the sigmoid fossa of the radius and the lateral facet on the head of the ulna; which is limited above by the inferior portion of the interosseous membrane, and in front and behind by the anterior and posterior radio-ulnar ligaments: and the *other* between the facet at the extremity of the ulna and the upper surface of the fibro-cartilage; which is limited on the inner side by the fixation of the fibro-cartilage to the pit in the ulna, and by the internal lateral ligament of the wrist which unites with the fibro-cartilage, and in front and behind by those fibres of the radio-ulnar ligament which are attached to the margins of the fibro-cartilage.

THE LOWER END OR HEAD OF THE ULNA is of smaller size than the head of the radius, which rotates in the annular ligament of the superior joint. It is two inches or thereabouts in circumference, exceeding the circumference of the shaft immediately above it by half an inch or more. At its base this rounded end of the ulna presents (1) a smooth, nearly circular surface, convex from side to side and from before back-than any other structure in either the upper or lower radio-ulnar joint.

The ligaments which close in the joint in front, behind, and above, and which with the fibro-cartilage form a boundary or capsule for it, are the lower end of the interosseous membrane and the anterior and posterior inferior radio-ulnar ligaments.

The *interosseous membrane* at quite its lower end passes between ulna and radius just above their points of contact. Sometimes a strong oblique band passes from the radius to the back of the head of the ulna; sometimes a strong oblique band—the inferior oblique ligament—passes from the ulna to the posterior margin of the sigmoid cavity of the radius, and always there are transverse or slightly oblique fibres between the two bones. Where these latter fibres are attached to the radius they form a sort of arch along the upper margin of the articular facet, so as to be continuous with the anterior and posterior radio-ulnar ligaments, and thus to cover in the synovial sac above.

The *anterior radio-ulnar ligament* is attached by one end to the anterior edge of the sigmoid cavity of the radius, and by the other to the rough bone above the articular surface of the ulna as far inwards as the notch on the anterior aspect of the head, as well as into the margin of the triangular fibro-cartilage from base to apex.

The *posterior radio-ulnar ligament* is similarly attached to the posterior margin of the sigmoid cavity at one end, and at the other to the rough bone above the articular surface of the head of the ulna as far inwards as the groove for the extensor carpi ulnaris tendon, and also into the posterior margin of the fibro-cartilage from base to apex. The sheath of the extensor carpi ulnaris tendon is closely connected with this ligament.

These ligaments consist of thin, sometimes almost scattered fibres, but they serve to complete a capsule for the support and protection of the synovial membrane. They also put some restraint, though probably not much, on supination and pronation, for when, in the dissected state of the forearm, forcible pronation is made, the posterior ligament bursts so as to allow of the lateral articular surface of the ulna being seen.

THE SYNOVIAL MEMBRANE, sometimes called the membrana sacciformis, is large in proportion to the size of the joint, and loose. It is not only interposed between the radial and ulnar articular surfaces, but it is continued uninterruptedly inwards to the terminal articular surface of the ulna and the upper surface of the triangular fibro-cartilage.

THE ARTERIES which supply this articulation are derived from the anterior and posterior interosseous and from the carpal arch.

1. The anterior interosseous sends a terminal branch along the fore surface of the interosseous membrane as far as the articulation, which it then supplies.

2. The posterior interosseous artery sends two or three twigs along the course and within the sheaths of the extensor tendon. From those running with the common extensor of the fingers and the extensor of the little finger, small twigs pass forwards into the joint.

3. The carpal arch, formed by the anterior ulnar and anterior radial carpal arteries, passes over the front of the radio-ulnar articulation, and gives branches to it as well as to the wrist-joint.

THE NERVES.—1. The median nerve through the terminal twigs of its interosseous branch supplies this joint; as does also, 2, the posterior interosseous nerve, which before it terminates on the back of the carpus in a gangliform enlargement gives off filaments to this as well as to other neighbouring joints and their ligaments.

Thus both the nerves which supply the muscles moving the bones at this joint, supply also the joint. The pronator radii teres and the flexor carpi radialis are supplied by the trunk of the median, the pronator quadratus, and the joint by the anterior interosseous branch of the median. The supinator longus is supplied by the musculo-spiral, the supinator brevis, the extensors, and the joint by the posterior interosseous branch of the musculo-spiral.

The biceps muscle is a very powerful supinator, but acts chiefly upon the upper end of the radius at the superior radio-ulnar articulation; it is supplied by a nerve which also supplies the superior joint—viz., the musculo-cutaneous.

THE MUSCLES.—The muscles in relation with this joint are the supinator longus and the pronator quadratus, together with all the extensors and flexors which pass over the wrist to the hand. Those most directly in relation with the articulation are, in front, the superficial and deep flexors of the fingers and the flexor carpi ulnaris; and behind, the extensor communis digitorum, the extensor minimi digiti, and the extensor carpi ulnaris.

All the muscles which have been described under the superior radio-ulnar joint as moving it, must necessarily move the inferior articulation also.

THE MOVEMENTS.—The movements of the lower end of the radius may be as easily deduced from the ligaments and fibro-cartilage of the inferior radio-ulnar joint as are the movements of the head of the radius from the anatomy of the superior.

The shape of the articular surfaces and the attachment of the triangular cartilage alike point to the turning or rotation of the lower end of the radius upon the head of the ulna, since there is almost a complete identity between the point of attachment of the fibro-cartilage to the ulna and the centre of the circle of which the sigmoid fossa of the radius is the arc. But the movements of the radius *as a whole* are not so readily understood from a consideration of the anatomical peculiarities of these joints. By many good anatomists they have been described as consisting in a rotation of the radius on its own axis; it is to Mr. Ward, however, that we are indebted for the correction of this error and for giving us a precise account of the combined movements of the radius. It was he who pointed out that the axes of the head and neck of the radius (*i.e.*, the axis of rotation of the upper end of the bone), and of the lower extremity or head of the ulna (*i.e.*, the axis of rotation of the radius below), form different portions of one and the same axis line, and that this line is the axis of the movements of the bone as a whole. This, he goes on further to explain, is why the partial rotation of the bone is unassociated with any hinge-like or antero-posterior motion of its head; and why pronation or supination, and the simultaneous advance and inward movement, or retrogression and outward movement respectively of its lower extremity, occur "without disturbance to the parallelism of its superior joint."

It will be readily conceived from the shape of the greater sigmoid fossa of the ulna and the truly hinge-like manner in which it is locked upon the trochlea of the humerus, that no rotation whatever can occur of this bone independent of that of the humerus itself at the shoulder-joint. And also that owing to the necessity of strong flexion and extension movement at the wrist as well as at the elbow, and to the fact that these movements are best provided for by a ginglymoid joint, the form of the *wrist-joint* is not suited to the rotatory movements of pronation and supination. Yet such rotation is requisite to allow of the alteration of aspect of the hand, *i.e.*, to allow of our at one time turning the palm upwards and at another downwards.

This requirement is met by the articulations between the two bones of the forearm, and is indeed the immediate cause or necessity of the existence of two bones in the forearm.

At the same time it is necessary that one of these two bones (the radius) whilst having the hand attached to it so as to move with it, must be associated with the humerus only in the flexion and extension movements of the elbow, but must be independent of it, as regards rotation; whilst the other bone of the forearm must supply the " terminal fixatures" of the rotating shaft. All this is accomplished by giving the radius a very limited share in the construction of the elbow, and the ulna but very little participation in that of the wrist-joint.

The extremes of the rotation of the lower end of the radius constitute the states of pronation and supination; in neither of these positions are the bones parallel to one another, or the whole of the interosseous membrane evenly extended between them. In supination there is a greater approach to parallelism than in pronation; in pronation the bones are quite athwart one another. The only position in which they are parallel, and in which the interosseous membrane is uncoiled throughout, is the mid-state between pronation and supination, when the thumb is directed upwards. For this reason this position is the one selected for the application of splints in the treatment of fractures of the upper limb.

In the dissected subject, with the posterior inferior radio-ulnar ligament ruptured, these extremes of rotation amount to complete opposition of direction, *i.e.*, to 180°, and even to a distance beyond this, amounting sometimes to nearly another 90°, when it is checked by the contact of the root of the styloid process of the ulna against the anterior margin of the sigmoid cavity of the radius, the twist of the internal lateral ligament of the wrist, and by some of the innermost fibres of the posterior ligament of the wrist; only the lowest and a few of the middle fibres of the interosseous membrane where the bones arch away from one another are on stretch, the rest with the oblique ligament are relaxed.

But in the undissected state the extremes of rotation, *i.e.*, of pronation and supination, amount only to a quadrant and a half, *i.e.*, 135°, so that neither the palm of the hand nor the fore surface of the lower end of the radius can be turned quite into completely opposite directions. This may be proved by fixing the elbow on a flat surface and carrying the bent forearm and hand from extreme supination into extreme pronation. Yet in the living body pronation and supination may be carried far beyond this limit of radial rotation, by the aid of the rotation of the humerus inwards and outwards respectively, for then the hand, when the elbow is extended, may be carried through even a greater number of degrees of a circle than in the dissected state above referred to. This may be proved by holding the slightly bent forearm downwards and carrying the lower end of the humerus (and olecranon with it, of course) outwards and upwards at the same time that the hand is pronated. By these movements not only is the radius rolled inwards and the palm carried backwards with it, but the lower end of the ulna is also carried outwards and upwards. In this way the structures which were checking pronation, when the humero-ulnar shaft was fixed at the shoulder-joint, become relaxed, and allow of still further rotation of the lower end of the radius on the head of the ulna, *i.e.*, of more complete pronation.

The structures which check pronation in the living subject are the posterior inferior radio-ulnar ligament, strengthened by the connexion of the sheaths of the extensor tendons with it; by the lowermost fibres of the interosseous membrane, and a few of its middle and strongest ones; by the back part of the internal and the internal fibres of the posterior ligaments of the wrist-joint, and by the meeting of the soft parts on the fore surface of the forearm.

Both in the dissected and the living subject supination is checked chiefly by the internal lateral ligament of the wrist-joint, but also by the oblique radio-ulnar ligament as well as by the anterior inferior radio-ulnar, and the lowermost fibres of the interosseous ligaments.

It has not been sufficiently represented by writers on anatomy that the rotation of what I will here call the humero-ulnar shaft at the shoulder-joint, increases the range of pronation of the hand; and certainly it seems to have been quite overlooked that the rotation of the radius around the axis line above described, is not the only movement of which the radio-ulnar articulations permit. Although in a general way, and especially in all movements to which the terms pronation and supination are usually confined, the ulna furnishes the terminal fixatures upon which the radius rotates, yet sometimes the *radius* supplies the terminal fixatures for the rotation of the ulna in exactly a converse manner, *i.e.*, the lesser sigmoid fossa of the ulna turns upon the head of the radius in the arc of a circle, whose centre is the centre of the radial head; whilst at the lower end, the head of the ulna rotates within the sigmoid cavity of the radius around the axis drawn through the attached apex of the triangular fibro-cartilage. In other words, the axis of movement is exactly the same as in ordinary pronation and supination, only the ulna, and not the radius, is the moving bone. The range of this rotation of the ulna is, it is true, limited in the living, though very extensive in the dissected limb, and is effected by rotation of the "humero-ulnar" shaft when the hand is fixed, as for example in vaulting, or in fixing firmly one hand on the back of a chair and walking round the seat; the movement of the styloid process of the ulna may then be plainly felt or seen.

That this movement is by no means one of slight importance, becomes evident enough when it is remembered that without it there could be no rotation of the humerus at the shoulder-joint as long as the hand and the lower end of the radius remained fixed. The reason it has been overlooked is probably because of the absence of any muscles in the forearm which at first sight could move the ulna on the radius; but if the humero-ulnar shaft be regarded as a rigid rod, it becomes obvious that the muscles which rotate the humerus also rotate the ulna upon the fixed radius: and further, some of the muscles which pronate and supinate the radius will, when the hand is fixed, have the reverse action on the ulna.

It has been previously stated that pronation and supination as ordinarily employed are associated respectively with abduction and adduction of the forearm and hand, due to rotation at the shoulder. Were this not the case the hand could not be turned over and back again, round an axis drawn through the middle of the hand, but would rotate upon the inner border of the hand.

CHAPTER XIV.

THE LIGAMENTS AND JOINT OF THE WRIST, OR, THE RADIO-CARPAL ARTICULATION.

Class, Diarthrosis. *Subdivision*, Ginglymus (with double-hinge action).

THE wrist is a *double-hinge joint* allowing of movement round a transverse axis, *i.e.*, flexion and extension; and around an antero-posterior axis, through the lower end of the radius, *i.e.*, of abduction and adduction. It also, as a matter of course, permits of a combination of these various movements, *i.e.*, of circumduction, so that it possesses most of the movements of a ball-and-socket joint, without having the weakness and the liability to displacement which is peculiar to the circular and free-moving enarthrodial joints. It lacks, however, that important adjunct of the ball-and-socket joints, rotation round a vertical axis; no rotation whatever is permitted at it. But this deficiency of the wrist-joint is made good to the hand, through the radio-ulnar articulations, at which, as has been already fully explained, rotation of the forearm and hand takes place round an axis through the head of the radius, the head of the ulna, and the finger of the hand. Thus do we see at the wrist and in the mode of union of the radius and ulna, a very similar, but, as the special requirements of the parts demand, somewhat different method for producing the same results as are found in the junction of the head with the spine. There also do we find two sets of articulations—(1) those between the occiput and atlas, at which flexion and extension, abduction and adduction (*i.e.*, lateral flexion to either side and back again), as well as circumduction take place; and (2) those between the axis and atlas, at which rotation round a vertical axis occurs.

The wrist-joint, by possessing the possibility of abduction and adduction, is by so much a more complicated hinge than either the elbow or the ankle, at which flexion and extension are really the only possible appreciable movements. The lateral movements which are permitted to the foot occur not at the ankle, but between the os calcis and astragalus, and at the medio-tarsal articulation; so that what is done freely by the hand at one joint, viz., radio-carpal, is less perfectly and freely performed by the foot at, at least, three sets of articulations.

The strength of this joint is not dependent upon any deep socket as at the hip; is not guarded by any overhanging processes as is the shoulder; has no strong and long lateral buttresses like the ankle, but only short and diminutive styloid processes; is not shut in behind an eminence as is the jaw, and is not locked securely by hook-like processes as is the elbow. Neither does its strength lie, like that of the knee, in the number, size, or arrangement of the ligaments which unite the bones; but rather in the number of tendons which pass over the joint, and in the close connexion which exists between the fibrous tissue of the sheaths of these tendons and the capsule of the wrist. And another additional source of strength to the wrist is its proximity to two other rows of joints—viz., the middle carpal, and the carpo-metacarpal; and the fact that each row has its own separate parts united by other arthrodial joints. Thus not only the movements, but shocks and jars, and all violence are shared between and distributed amongst all the several articulations. At no one of them, however, except the wrist, are the movements at all free, and yet the aggregate motion is considerable. Another source of security lies in the fact that a long lever does not exist on the distal side of the joint.

The wrist is the junction of the hand with the forearm, and is formed by the union of the radius and the triangular fibro-cartilage above, with the scaphoid, semilunar, and cuneiform bones of the carpus below. The ulna is excluded from the wrist-joint by the intervention of the fibro-cartilage. The radius and triangular fibro-cartilage together present a smooth surface, slightly concave both from before backwards, and from side to side; whilst the three bones of the carpus present a corresponding smooth convex surface, made uniformly even and uninterrupted by the interosseous ligaments between the scaphoid and lunar, and the lunar and the cuneiform.

The bones which, so far as they enter into the formation of the wrist-joint, now require description, are—the radius, the scaphoid, the semilunar, and the cuneiform.

THE RADIUS.—The lower end of the radius is much larger than the upper, and presents a somewhat quadrilateral outline, and is so curved as to present a slight concavity in front, and a slight convexity behind. It usually measures over an inch from side to side, and three-quarters of an inch from before backwards at its centre. Its extremity is marked by a large triangular articular facet, which is somewhat prolonged downwards upon the styloid process of the bone. The apex of this facet is placed at the styloid process, and the base is formed by the sharp edge which separates the inferior articular surface from the sigmoid cavity of the radius, and gives attachment to the broad extremity of the triangular fibro-cartilage. The anterior and posterior margins of this surface are somewhat projecting, the anterior being slightly more so than the posterior, and give the articular surface its slightly concave character; and to the rough surface of bone, just above them, the anterior and posterior portions of the capsular ligament are attached. Owing to the slight curve forwards in the lower end of the radius, this facet looks slightly forwards as well as downwards; it has also a very slight inclination inwards. The facet is divided into two parts by an antero-posterior ridge extending across the surface, and by a slight indentation, or hour-glass contraction of its margins. An inner quadrilateral portion, nearly half an inch wide by three-quarters of an inch from before backwards, articulates with the semilunar bone; and an outer and triangular-shaped portion, about five-eighths of an inch wide, varying in measurement from before backwards at different points, and becoming smaller towards the apex of the triangular area, articulates with the scaphoid. At the inner side of the extremity, and placed at right angles to the facet for the scaphoid, is the sigmoid fossa for the ulna, which has been described under the inferior radio-ulnar articulation.

At the outer side a conical process, *the styloid process*, is prolonged downwards from a very narrow surface; it is about a quarter of an inch long, and is thus the lowermost point of the radius. To the base of this process is attached the supinator longus, and to the tip the external lateral ligament of the wrist.

The anterior surface immediately above the articular edge is rough and uneven, and is marked by a ridge which extends outwards from the margin of the sigmoid cavity to the ridge in front of the tendon of the extensor ossis metacarpi pollicis, and then curves downwards on the front of the styloid process to its tip. Below the ridge is an uneven depression which gives attachment to some very strong oblique anterior fibres of the capsular ligament of the wrist. Where this ridge curves downwards, it is joined by another, which descends almost vertically from the outer side of the shaft, and forms the front limit of the groove for the extensor ossis metacarpi and extensor primi internodii pollicis; this groove is a little in front of the plane of the apex of the styloid process.

The posterior surface is convex and irregular, being marked by grooves and ridges for the passage of the tendons of the extensor muscles. Thus a prominent rough ridge descends upon the outer surface of the styloid process to its tip, where it meets with the ridge which descends on the anterior surface of the process; it separates the groove for the extensor ossis metacarpi and extensor primi internodii pollicis from the broad groove for the radial extensors of the wrist. This groove is again divided by a faint ridge between the long and short radial extensors, and to its inner side and nearly in the middle of this surface of the bone is a prominent rough ridge, which is continued upwards on the back of the shaft and bifurcates, the outer portion ascending to the rough surface of insertion of the pronator radii teres, while the other joins the interosseous border of the bone in its lower third. Under cover of this ridge and to its inner side is a groove for the extensor secundi internodii pollicis, and to the inner side of this again is a broad groove for the extensor communis digitorum and extensor indicis.

These tendons increase considerably the security of the wrist-joint.

The radius, like the ulna, undergoes a great change of form from end to end; thus instead of being cylindrical, as above, it becomes much expanded and assumes the quadilateral outline. This expansion is at the expense of its solidity, for a section of the bone shows its compact wall to be very thin.

THE FIRST ROW OF THE CARPAL BONES.—The scaphoid, semilunar, and cuneiform bones present superiorly a surface which is smooth, covered with articular cartilage, except over the interosseous ligaments, pretty uniformly convex, and directed upwards and slightly backwards. The articular facetted surface of these bones extends further on the dorsal than the palmar aspect; that of the *scaphoid* is triangular in form, and articulates with the outer facet on the lower end of the radius, and through its medium the metacarpal bones of the thumb and forefinger are indirectly supported on the radius.

The *semilunar* presents a quadrilateral-shaped facet in correspondence with the inner portion of the lower end of the radius; through the os magnum it bears the middle or longest and most prominent finger, and therefore the one most liable to be injured, upon the strongest part of the radius.

The *cuneiform* presents a triangular-shaped facet for the fibro-cartilage, which is interposed between it and the ulna; it supports the unciform bone, and transmits pressure from the little and ring fingers to the end of the ulna.

The cuneiform and scaphoid bones rest upon the fibro-cartilage and the outer part of the radius respectively in a slanting manner. This is necessarily so on account of the arch into which they are received, but a result of it is that a portion of the forces received by them is transmitted to the semilunar bone which rests more perpendicularly upon the radius, and that too upon the largest and strongest part of the radius.

THE TRIANGULAR FIBRO-CARTILAGE.—The ulna is excluded from the wrist-joint by the triangular fibro-cartilage, which besides presenting a concave under surface for the cuneiform of the carpus, presents also a concave upper surface for the head of the ulna. To its margins the loose fibrous capsule of the inferior radio-ulnar, as well as the capsular ligament of the wrist joint, is attached; and as the cartilage stretches transversely below the ulna, from the inner border of the radius to the fossa at the root of the styloid process of the ulna, it assists in forming the boundary of each articulation.

It is about three-quarters of an inch from base to apex, and half an inch from before backwards at the base. Its edges are very ill-defined, owing to the quantity of ligamentous fibres connected with it, and near its apex it is blended intimately with the internal lateral ligament of the wrist.

By its base it is connected with the projecting anterior and posterior ridges of the sigmoid cavity of the radius, as well as with the angular line which separates the facet for the ulna from that for the semilunar bone of the carpus.

The inferior surface of the cartilage is almost on the same plane with the terminal articular surface of the radius, but slopes downwards considerably towards its apex, so as to form with the radius the arched superior surface of the wrist-joint. This arched surface is somewhat oval or diamond-shaped, being considerably narrower at the inner and outer ends, viz., at the styloid processes, than at the inner part of the radial surface; the anterior and posterior borders of the radial surface gradually approximate as they pass towards the styloid process. The outer lateral buttress of the arch, *i.e.*, the styloid process of the radius, has the articular surface prolonged down upon it.

THE CAPSULE, OR CAPSULAR LIGAMENT, OF THE WRIST.—The capsule of the wrist-joint has been usually described as four separate ligaments, and it will be convenient for the sake of a complete description to follow this method; but it must at the outset be understood that these four portions form one continuous and uninterrupted structure, extending from styloid process to styloid process on both aspects of the joint. Considered as a whole, the capsule arises from the margins of the lower end of the radius; from the margins of the triangular fibro-cartilage, where it blends with the anterior and posterior inferior radio-ulnar ligaments; and from the edges and surfaces of the styloid process of the ulna. It is attached below to the bones of both rows of the carpus, and thus adds strength to the union of the several carpal bones with one another. More especially is this the case on the palmar aspect, where it forms the floor of the sheath upon which the flexor tendons glide just before they pass beneath the annular ligament of the carpus. This ligamentous envelope is strengthened by superadded fibres, both in front and behind (*i.e.*, on palmar and dorsal aspects), which pass on to the carpal bones from the little irregular rough points at the lower ends of the radius and ulna; and some very strong additional fasciculi of fibres strengthen the sides of the capsule and radiate from the styloid processes upon the bones of the carpus so as to form lateral ligaments suitable for and necessary to the hinge-like character of the articulation.

The *anterior radio-carpal ligament*, *i.e.*, the anterior portion of the capsule of the wrist, is attached superiorly to the radius immediately above the margin of the terminal articular facet, to the curved ridge at the root of the styloid process of the radius, and to the anterior margin of the triangular fibro-cartilage, where it is blended with some of the fibres of the capsule of the inferior radio-ulnar joint. Thence they pass downwards, and for the most part inwards, to be connected with both rows, but specially with the second row of the carpus and with the fibrous tissue connecting the two rows with one another, *i.e.*, the anterior intercarpal ligament. The strongest and most oblique fibres arise from the curved ridge at the root of the styloid process of the radius, and from the large uneven depression between it and the margin of the facet for the scaphoid; only a few of these fibres have any connexion with the scaphoid itself, the rest pass obliquely over it, and are inserted into the semilunar, the os magnum, and the cuneiform bones. Another strong but less oblique set passes from the radius, above the margin of the facet for the semilunar bone, to be attached to the adjacent parts of the os magnum, unciform, and cuneiform bones. Between the two sets of fibres, small vessels pass through the capsule into the joint.

The obliquely inward direction of the fibres of this portion of the capsule gives to it the power of dragging over the hand with the radius in the powerful movements of supination, and in this they are assisted by the *anterior portion* of the *external* lateral ligament, whose fibres have the same direction, whilst the fibres of the *anterior portion* of the *internal* lateral ligament have an opposite direction, and therefore tend to check supination. The anterior radio-carpal ligament also checks or limits extension of the wrist.

The *posterior radio-carpal ligament*, *i.e.*, the posterior part of the capsule of the wrist, is attached superiorly to the dorsal edge of the carpal end of the radius and to the back of the styloid process of the radius, as well as to the posterior margin of the triangular fibro-cartilage. It passes downwards and inwards to be connected with the first row of carpal bones, and to the ligament connecting the first with the second row, but chiefly to the semilunar and the cuneiform. If the joint be laid open, and the ligament held up to the light, some parts of it will appear opaque and others transparent. On dissection, the thick opaque parts are found to have the following connexions:—

(1) Some strong fibres pass from the back of the fibro-cartilage, where they are blended at their origin with the posterior inferior radio-ulnar ligament, and from the edge of the radius just behind the sigmoid fossa, to be attached to the cuneiform bone. (2) From the prominent ridge and the groove for the extensor

secundi internodii pollicis to the back of the semilunar and cuneiform bones. And (3) from the groove for the radial extensors (which includes the posterior surface of the styloid process), to the back of the scaphoid and the semilunar.

This posterior ligament is not so strong as the anterior; it is in relation with the sheaths of the extensor tendons which pass over it. It limits flexion of the hand, and from the obliquely downward and inward direction of its fibres, it carries the hand with the radius in pronation.

The *internal lateral ligament, i.e.,* the inner side of the capsule of the wrist-joint, is fan-shaped, with its apex above at the styloid process of the ulna. It is attached to the styloid process of the ulna on all sides, and blends with the apex of the fibro-cartilage. Some of the fibres, as they descend to the carpus, pass obliquely forwards and outwards to the base of the pisiform bone, and to the inner part of the upper border of the anterior annular ligament of the carpus, where that ligament springs from the pisiform bone; these fibres form a round, thick, and prominent fasciculus on the front aspect of the wrist, and whilst they assist the anterior ligament and the anterior portion of the external lateral ligament in limiting extension, they counteract them by limiting instead of facilitating supination. Other fibres pass down vertically to the inner side of the cuneiform bone, and others again outwards and downwards to the dorsal surface of the cuneiform. These latter fibres assist in limiting pronation. The tendon of the extensor carpi ulnaris is posterior to, and passes over, part of the fibres of this ligament.

Besides its influence in limiting pronation and supination, and the assistance given by the long anterior fasciculus to the anterior ligament in limiting extension, the whole ligament acts to limit abduction of the wrist, which is the least extensive movement of the joint, not only on account of the strength of this ligament, but also because the styloid process impinges against the scaphoid bone in the extreme of this movement.

The *external lateral ligament, i.e.,* the outer part of the capsule of the wrist, consist of fibres which radiate from the extremity and forepart of the styloid process of the radius. Of these some pass downwards and inwards in front to the scaphoid and the adjacent edge of the os magnum; others downwards, and a little forwards and inwards, to the tubercle of the scaphoid and the ridge of the trapezium; and others again downwards, and a little outwards, on to the rough dorsal surface of the scaphoid. The fibres of this ligament do not radiate so much, nor are they so long or strong, as those of the internal lateral ligament.

The radial artery passes over this ligament, and so do the extensor ossis metacarpi, and extensor primi internodii, pollicis. The artery separates these tendons from the ligament.

This ligament limits adduction. By its anterior fibres it assists the anterior ligament and the anterior portion of the internal lateral ligament to limit extension. By its anterior fibres, which like the anterior ligament itself pass obliquely downwards and inwards, it drags or carries over the hand in the powerful movements of supination. Supination being a more powerful movement than pronation, the hand has therefore the additional advantage and security of these fibres of the external ligament, although the anterior ligament is itself stronger than the posterior, which carries the hand with the radius in the movement of pronation. At the same time there is provided in the anterior portion of the internal lateral ligament a very powerful check over supination.

The *posterior annular ligament* of the wrist assists the posterior portion of the capsule of the wrist-joint in binding the hand to the forearm, and in carrying the hand with the radius in pronation. It is a strong fibrous band, extending somewhat obliquely across the back of the joint, with an inclination downwards and inwards. It is attached externally to the posterior margin and the ridges on the hinder surface of the radius, and internally to the cuneiform, pisiform and base of the fifth metacarpal bone. The superior fibres bind down the extensor carpi ulnaris tendon, and on their way to the carpus pass below the end of the ulna. As it passes across the wrist some of its fibres are attached to the ridge on the back of the radius. Above, it is continuous with the fascia of the forearm. The subway between its deep surface and the wrist is divided into six compartments for the passage of the extensor tendons. Thus this ligament serves three distinct purposes—(1) it binds down the extensor tendons, keeping them in their places as they pass over the convex dorsal surface of the carpus, and giving to them their proper direction, which, from their obliquity in the forearm, they would not otherwise get; (2) it strengthens the connexion between the forearm and the hand; and (3) it assists the posterior radio-carpal ligament in dragging the hand over with the radius in the movement of pronation.

THE SYNOVIAL MEMBRANE.—The synovial membrane of the wrist-joint is very extensive, but has the same relation to the other structures as in simple joints, *i.e.*, where there are only two bones in their construction. It does not communicate usually with the inferior radio-ulnar articulation, being shut off from it by the triangular fibro-cartilage; nor with the joints between the bones of the first row of the carpus, being shut out from them by the interosseous ligaments which make even and uniform the convexity of the carpal portion of the joint. The styloid process of the radius (but not of the ulna) is cartilage-coated, and comes within the limits of the synovial sac. Outside the synovial membrane along the posterior border of the radius a few fatty processes project, fringe-like, into the articulation.

THE ARTERIES.—(1) The arch formed by the two anterior carpal branches from the radial and ulnar trunks is in front of the articulation. It lies beneath the median nerve and the synovial apparatus of the flexor tendons as they pass the wrist, and in immediate contact with the anterior portion of the capsule of the joint. This arch receives tributaries from the descending branches of the anterior interosseous, and a recurrent or ascending branch from the deep palmar arch. Twigs from these sources ramify deeply in the substance of the ligament, and form a more or less complete zone beneath the synovial membrane. This zone is close to the edge of the articular surface of the bones, and from that part of it upon the carpal bones little vessels are sent along upon the two interosseous carpal ligaments.

(2) On the back of the articulation there are (*a*) recurrent branches from the posterior carpal arch, and (*b*) from the first dorsal interosseous artery; and (*c*) branches from the posterior interosseous. The posterior interosseous, or posterior termination of the anterior interosseous, forms a free anastomosis with branches from the radial and ulnar, which curve round the respective bones, and from the chain thus formed twigs run along in the synovial sheath of each of the tendons, supplying the sheath and giving filaments to the tendons. From these branches to the sheath and tendons vessels enter the back of the wrist and carpal joints.

(3) Piercing the external lateral ligament, and thus entering

immediately into the wrist-joint, are twigs derived from the radial as that vessel passes over the external lateral ligament.

(4) Similarly others enter the wrist from the ulnar on the inner side, while others penetrate the internal lateral ligament to reach the inter-articular cartilage and the inferior radio-ulnar joint.

THE NERVES.—In front, the ulnar and the median; and behind, the posterior interosseous. Each gives filaments to this joint.

THE MUSCLES.—The muscles in connexion with, or which move the wrist-joint, are all those which pass over it to be inserted into some parts of the bones of the hand. Thus, in front there are the superficial and deep flexors of the fingers, the flexor longus pollicis, the flexor carpi ulnaris and flexor carpi radialis, and the palmaris longus. Behind, there are from without inwards the radial extensors major and minor, the extensor secundi internodii pollicis, the extensor communis digitorum and extensor indicis, the extensor minimi digiti and the extensor carpi ulnaris. And on the outer side, the extensor ossis metacarpi pollicis, and extensor primi internodii pollicis.

The action of the muscles on the wrist-joint can be easily surmised from their relation to it, and from their names.

Flexors.—*Flexion* of the wrist is effected primarily by the two flexors of the carpus—viz., the flexor carpi ulnaris and flexor carpi radialis; but when flexion of the fingers is either prevented or completed, then all the flexors of the digits act to flex the wrist; so with the palmaris longus, which, when its action in tightening the palmar fascia is completed or prevented, also assists to bend the wrist.

Extensors.—*Extension* of the wrist is produced primarily by the three extensors of the carpus—viz., the extensor carpi ulnaris, extensor radialis major, and extensor radialis minor; but all the long extensors of the fingers assist in extending the wrist when their action on the fingers is prevented or completed.

Abductors.—The extensor carpi radialis longior and brevior, the flexor carpi radialis, and the extensor ossis metacarpi and primi internodii pollicis, acting unopposed singly or together, abduct the hand.

Adductors.—The flexor carpi ulnaris and extensor carpi ulnaris, acting unopposed singly or together, bend the ulnar edge of the hand downwards or towards the styloid process of the ulna, *i.e.*, adduct it.

In other words, if the extensors of the carpus act together, the hand is bent backwards, *i.e.*, extended; when the flexors of the carpus act together, the hand is bent forwards, *i.e.*, flexed; and when the flexor and extensors of the carpus on the radial side act together (those of the ulnar side not acting), the hand is bent towards the radius, *i.e.*, abducted; but when the flexor and extensors on the ulnar side act together (those of the radial side not acting), the hand is bent towards the ulna, *i.e.*, adducted.

THE BURSÆ.—There are several bursæ in relation with the wrist, but like those about the ankle, and unlike those about the hip and shoulder, knee and elbow, they are nearly all of the form of synovial sheaths for tendons. Those on the front of the joint are (1) a large long bursa for the tendon of the flexor longus pollicis; this extends from above the line of the wrist, all along the palm to the thumb, near the insertion of the tendon. (2) Four short bursæ on the forepart of the tendons of the flexor sublimis. (3) A large bursa behind the tendon of the flexor longus pollicis, which intervenes between it and the front of the radius and capsule of the wrist. (4) A large bursa between the flexor profundus digitorum tendons, and the front of the lower end of the radius and the capsule of the wrist. Sometimes this communicates with the last. (5) A short oblong bursa surrounding the flexor carpi radialis, extending from above the wrist to the groove in the trapezium, and passing between the outer attachments of the annular ligament of the carpus, as shown in the plate illustrating the palm of the hand. (6) A small round bursa connected with the flexor carpi ulnaris, between it and the internal lateral ligament at its insertion into the pisiform bone.

On the outer side of the wrist there is a bursa separating the extensors of the thumb from the radius and capsule of the joint. On the back of the wrist a bursa is found in connexion with each tendon, or set of tendons, as they pass along the grooves in the bones at the back of the joint. The largest, and those in closest connexion with the joint, are—(1) one separating the radial extensors from the radius and capsule; (2) one separating the index and common extensors from the capsule; and (3) one separating the extensor carpi ulnaris from the capsule and ulna. The extensor minimi digiti, and extensor secundi internodii pollicis, are each provided with a bursa, or bursal sheath.

THE MOVEMENTS.—The movements of the wrist-joint are the four angular movements—flexion, extension, abduction, and adduction; and the movements of these combined, or made to follow each other in quick succession, *i.e.*, circumduction. In flexion and extension, the carpus rolls backwards or forwards respectively, beneath the arch formed by the radius and fibro-cartilage, moving round a transverse axis through the styloid processes. Flexion is limited by the posterior ligament, and posterior portions of the lateral ligaments; extension, by the anterior ligament, and the anterior portion of the lateral ligaments.

In abduction and adduction, the carpal bones glide from without inwards and from within outwards respectively, beneath the arch formed by the radius and fibro-cartilage, around an antero-posterior axis through the lower end of the radius. Abduction is more limited than adduction, and is checked by the long and strong internal lateral ligament of the wrist, and by the contact of the styloid process of the radius with the trapezium. Adduction is checked by the external lateral ligament alone. One reason for adduction being more free than abduction is because the ulna does not reach so low down as the radius, and the yielding fibro-cartilage allows of greater movement upwards of the inner extremity of the carpus. In circumduction, the hand moves so as to describe a cone, the apex of which is at the wrist. This last movement, like each of its components, is made more easy and more free and extensive by the slight gliding movement of the carpal bones on one another, and by the comparatively free movement permitted at the medio-carpal joint. It has been already fully pointed out that pronation and supination are not permitted in the least degree at the wrist, but take place at the radio-ulnar joints.

The oblique direction of the fibres of the lateral ligaments prevents any rotation at the radio-carpal joint, while it permits much freedom of abduction and adduction. In these latter movements both ligaments become somewhat relaxed by the approach of the carpus to the forearm on the side towards which the movement occurs, and the lateral shifting of the carpus towards the styloid process of the opposite side.

CHAPTER XV.

THE JOINTS AND LIGAMENTS OF THE HAND.

THE hand, which is the inferior segment of the upper limb, is characteristic of man and the quadrumana. It might even be said to belong exclusively to man; for the anterior extremity of the monkey is as much a foot as a hand, indeed, as much as its posterior extremity is a hand; whereas in man the hand corresponds in its sensibility and varied movements to the superiority of his mental endowments over all other animals; and the two together—mind and hand—make him the ruler over the rest of nature. All the other parts of the superior extremity, from the shoulder downwards, are subservient to the uses and functions of the hand: the strength and freedom of motion of the ball-and-socket joint of the shoulder, the security of the hinge of the elbow, the pronation and supination between the bones of the forearm, the strength and gliding angular movements of the wrist, are all provisions for the easy, rapid, varied and powerful actions of the hand. The skeleton of the hand consists of twenty-seven distinct bones, and these are united together by means of ligaments—dorsal, interosseous, and palmar—and their movements upon one another facilitated by synovial membrane. In the hand are subdivisions analogous to those in the foot; thus the *carpus* corresponds to the tarsus, the *metacarpus* corresponds to the metatarsus, and the phalanges of the fingers are in every way analogous to those of the toes.

But whilst in the foot *all* the toes are nearly parallel to the middle line of the foot, in the hand only the four inner digits are parallel to the middle line of the hand, and the thumb forms an angle with this line of rather more than 45°. This makes the carpo-metacarpal joint of the thumb a much more important articulation than any of the tarso-metatarsal joints; and is the cause of its requiring a special description.

We will take the several parts in the order named, beginning with the *joints and ligaments of the carpus.*

First, let us examine how the bones in each of the two rows of the carpus are joined together, and then how the two rows themselves are united.

Joints and Ligaments of the First Row of the Carpus.

Class, Diarthrosis. *Subdivision*, Arthrodia.

THE BONES.—In the first or upper row of the carpus the scaphoid, semilunar, and cuneiform bones form by their combined superior articular surfaces a convex surface adapted to the radius, and contributing to the formation of the wrist. The pisiform has a separate and independent articulation with the cuneiform.

The *scaphoid*, like each of the other carpal bones, has six surfaces. In most of these bones, four of the surfaces are articular, and two, the anterior and posterior, are rough for the attachment of ligaments. By its internal surface the scaphoid articulates with both the semilunar and the os magnum, and its smooth cartilaginous facets are separated by a horizontal crescentic ridge; the superior is directed inwards and forwards, and is narrow, semilunar, and flat, to articulate with the correspondingly shaped outer surface of the semilunar bone. The inferior and larger portion presents an oval-shaped and deeply concave facet, which looks inwards, forwards, and downwards, and assists in the formation of the socket for the head of the os magnum. By its outer surface, which is narrow and rough, and directed upwards and outwards, the scaphoid gives attachment to the external lateral ligament of the wrist.

The *semilunar bone*, by the whole of its external surface, articulates with the superior facet of the internal surface of the scaphoid. This surface is directed outwards and slightly towards the dorsum; it is narrow, semilunar, flat, and smooth, with a cartilaginous coating. Its internal surface is inclined in the opposite direction—viz., inwards and forwards, as well as slightly downwards: it is smooth, quadrilateral, and plane, or slightly convex for articulation with the cuneiform bone.

The *cuneiform bone* by its outer surface presents a smooth, flat, or slightly concave surface for the semilunar. This surface is quadrilateral in shape, with its superior angles somewhat rounded off, and it looks outwards, upwards, and backwards. The anterior surface is rough externally for ligaments of the wrist and carpus, and internally and below presents a smooth and nearly flat surface for the pisiform bone. The internal surface is small and non-articular; it is the lowest point of the bone, and is roughened for the attachment of the anterior annular ligament, and a fasciculus of the internal lateral ligament of the wrist.

The *pisiform bone* is placed on the front (*i.e.*, on the palmar) aspect of the cuneiform, with which it articulates by a smooth and nearly flat facet, upon its posterior, or dorsal, aspect. It is the smallest of all the carpal bones; presents no other articular surface, but is everywhere else rough for the attachment of muscles and ligaments, viz., the anterior annular ligament of the carpus; the internal lateral ligament of the wrist; the capsular ligament, which unites it with the cuneiform bone; the tendon of insertion of the flexor carpi ulnaris, and the fibres of origin of the abductor minimi digiti. Lastly, there are two distinct, strong fibrous bands uniting the pisiform to the process of the unciform and the base of the fifth metacarpal bone, but these are in truth only the prolongation downwards of the tendon of the flexor carpi ulnaris.

THE LIGAMENTS.—The bones of the first row, the pisiform excepted, are united by two sets of ligaments, and two interosseous fibro-cartilages.

Two dorsal ligaments extend transversely between the bones and connect the scaphoid with the semilunar, and the semilunar with the cuneiform. Their posterior surface is in contact with the posterior ligament of the wrist-joint.

Two palmar ligaments extend nearly transversely between the bones, and connect the scaphoid with the semilunar, and the semilunar with the cuneiform. They are stronger than the dorsal ligaments, and are placed beneath the anterior ligament of the wrist-joint.

The two Interosseous Fibro-cartilages.—Between the scaphoid and the lunar, as well as between the lunar and the cuneiform bone, there is interposed in the whole antero-posterior length of the articulation, *i.e.*, from dorsal to palmar surfaces, a narrow fibro-cartilage, which, however, extends between only a small portion of the osseous surfaces. These interosseous laminæ are best seen by laying open the radio-carpal joint, the convex carpal surface of which they help to form. They are attached to the palmar and dorsal ligaments by the anterior and posterior extremities. When dissected out they are seen to be somewhat wedge-shaped, with their thick edge towards the wrist-joint, and their thin edge between the adjacent articular surfaces of the bones.

These laminæ are usually described as ligaments, but their real structure is fibro-cartilaginous.

The SYNOVIAL MEMBRANE of these small articulations, like that between the bones of the second row of the carpus, is merely a prolongation from the large synovial membrane between the two rows themselves.

Ligaments connecting Pisiform Bone with the Carpus.—The pisiform bone articulates with the cuneiform, so as to form a separate joint, and takes no part in the construction of the wrist. A small loose fibrous capsule is attached to both the pisiform and cuneiform, just beyond the margin of their articular surface for one another, and this is lined by a separate and distinct synovial membrane.

Two strong rounded or flattened bands pass downwards from the pisiform, one to the process of the unciform, and the other to the base of the fifth metacarpal bone. These, however, are to be regarded as prolongations of the tendon of the flexor carpi ulnaris muscle, and the pisiform itself may be looked upon as a sesamoid bone developed in that tendon, as the patella is in that of the quadriceps extensor femoris.

Joints and Ligaments of the Lower Row of the Carpus.

THE BONES.—In this row the trapezium, the trapezoid, the os magnum, and the unciform follow one another in order from the radial to the ulnar side. By their united superior articular surfaces they are adapted to the united inferior articular surfaces of the upper row (the pisiform bone excepted), and thus contribute to form the "medio-carpal articulation," whereas by the inferior articular surfaces they enter into the construction of the carpo-metacarpal joints.

The *trapezium* by its *internal* surface articulates with the second bone of this row, viz., the trapezoid. This surface is divided by a horizontal ridge into two parts; one, the upper and larger portion, is concave and looks inwards and backwards to articulate with the trapezoid; the other is directed downwards and inwards, and articulates with the side of the base of the second metacarpal bone. The external surface is rough and gives attachment to the external lateral ligament of the wrist.

The *trapezoid* is interposed between the trapezium and os magnum, articulating with the former by its external and with the latter by its internal surface. The external surface is convex, and directed outwards and forwards. The internal surface is concave and smooth over nearly its whole extent to articulate with the os magnum, but near the dorsum it is rough for the attachment of an interosseous ligament.

The *os magnum*—the central, the chief, and the largest bone in the carpus—presents a small facet on its outer surface for the trapezoid, and a large one on its internal surface for the unciform. The external surface, in addition to the small semicircular facet for the trapezoid, which is situated at its lower and anterior part, has above and behind this smooth surface a rough depression for the attachment of an interosseous ligament; above this again, a rough constriction, forming part of the neck of the bone; and above this again, the outer side of the smooth facetted head, which articulates with the scaphoid.

Thus a considerable part of this surface projects upwards beyond the line of the trapezium and trapezoid, and so fits into the hollow formed by the scaphoid and the lunar.

On the internal surface, besides the large concave articular surface for the unciform, which extends over the side of the head as well as the neck and body of the bone, there is anteriorly a rough depression for the attachment of an interosseous ligament; this rough space does not quite reach to the dorsal, but extends right down to the palmar surface of the bone in correspondence with the rough portion of the apposed surface of the unciform.

The *unciform bone* presents on its outer side an irregularly shaped articular facet for the os magnum. It occupies nearly the whole of this aspect of the bone, excepting a small square, rough, and non-articular portion at the anterior inferior corner, where an interosseous ligament is attached.

THE LIGAMENTS.—The four bones of this row are united to one another by three dorsal, three palmar, and two interosseous ligaments.

The *three dorsal ligaments* extend transversely and connect the trapezium with the trapezoid, the trapezoid with the os magnum, and the os magnum with the unciform.

The *three palmar ligaments* are stronger than the dorsal, and are deeply placed beneath the mass of flexor tendons and the anterior annular ligament of the carpus. They have the same relation and connexion with the several bones on their anterior as the dorsal ligaments have on their posterior aspect.

The *two interosseous ligaments* are situated one on each side of the os magnum, which they connect with the trapezoid on the outer and with the unciform on the inner side. That between the os magnum and trapezoid is attached to the apposed surfaces near their dorsal, *i.e.*, posterior aspect. That between the unciform and os magnum is attached to the apposed surfaces at their lower and anterior, *i.e.*, palmar aspect.

Like all articular bony surfaces the facets on these carpal bones which play upon one another are coated with a layer of articular cartilage.

The SYNOVIAL MEMBRANE, like that between the bones of the first row of the carpus, is a prolongation of the membrane belonging to the medio-carpal joint.

The Medio-carpal Joint, or The Articulation of the Upper with the Lower Row of the Carpus.

The inferior articular surfaces of the upper row, *i.e.*, of the scaphoid, semilunar, and cuneiform bones, are adapted to the superior articular surfaces of the bones of the second row. The line of this articulation is concavo-convex from side to side; thus the first row presents a wavy surface for the reception of the second. The outer or radial part of the first row, consisting of the scaphoid alone, is convex, and bears the trapezium and trapezoid. Then follows a large transversely elongated socket, formed by the deep concavity of the inner part of the scaphoid and the lower part of the semilunar and cuneiform, into which are received (1) the head of the os magnum, which articulates with both scaphoid and semilunar; (2) the upper and outer angle of the unciform, which articulates with the semilunar; and (3) the upper convex portion of the internal surface of the unciform, which articulates with the external and concave portion of the inferior surface of the cuneiform. Thirdly, the innermost part of the inferior surface of the cuneiform bone is convex and turned a little backwards to fit into the lower

The *three palmar ligaments* are stronger than the dorsal, and are deeply placed beneath the mass of flexor tendons and the anterior annular ligament of the carpus. They have the same relation and connexion with the several bones on their anterior as the dorsal ligaments have on their posterior aspect.

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Like all articular bony surfaces the facets on these carpal bones which play upon one another are coated with a layer of articular cartilage.

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THE LIGAMENTS.—The articular surfaces are covered by a thin layer of cartilage, and are held in apposition by the following ligaments:—

The *anterior, or palmar medio-carpal ligament,* which is of considerable strength, consists of fibres most of which radiate from the os magnum to the scaphoid, lunar, and cuneiform; some few others, however, connect the trapezoid and the trapezium with the scaphoid, and others again pass between the unciform and cuneiform. It is covered over and thickened by a quantity of fibrous tissue derived from the sheaths of the flexor tendons, and the fibres of origin of the small muscles of the thumb and little finger.

The *posterior, or dorsal medio-carpal ligament,* consists of fibres extending obliquely from the bones of the upper to those of the lower row. It is stronger on the ulnar than on the radial side, but not so strong as the palmar ligament.

Transverse Dorsal Ligament.—An additional ligamentous band, well-marked and often of considerable strength, which may be called the "transverse dorsal ligament" of the carpus, passes across the head of the os magnum from the back of the scaphoid to the back of the cuneiform bone. Besides binding down the head of the os magnum, it serves to fix also the upper and outer angle of the unciform in the socket formed by the upper row of bones. This is one of the ligaments which Cruveilhier called *glenoid ligaments,* but in front there is nothing worthy a special name.

osseous on the dorsal aspect of the carpus, which usually inosculate with the posterior carpal branches of the radial and ulnar.

THE NERVES.—The nerve supply is derived from—

(1) The posterior interosseous nerve; a branch of the great musculo-spiral trunk, through which, directly or indirectly, all the extensors and supinators of the forearm and hand, as well as the skin over the back of the carpus, metacarpus, and phalanges are supplied. The posterior interosseous terminates on the back of the carpus in a ganglion, from which filaments pass off to the adjoining ligaments and articulations.

(2) The median nerve supplies a few filaments to the radial side of the joint.

(3) The ulnar by its deep branch supplies those on the ulnar side of the third interosseous space.

THE MUSCLES.—Besides the muscles which pass over the front and back of the carpus to reach the phalanges or the bases of the metacarpal bones, there are in connexion with the carpal bones and their ligaments the small muscles of the thumb and little finger. Thus, taking the several bones in order, the following muscles are attachad to them:—

The scaphoid, semilunar, and cuneiform usually have no muscle connected with them.

The PISIFORM gives insertion to the *flexor carpi ulnaris*, and origin to the *abductor minimi digiti.*

The TRAPEZIUM, by its oblique ridge on the palmar aspect, gives origin to the *opponens*, *abductor*, and *flexor brevis pollicis.* The opponens (*i.e.*, the flexor ossis metacarpi) pollicis and the abductor pollicis are attached, the former to the trapezium, and the latter to the trapezium and sometimes to the scaphoid on the outer side of the attachment of the annular ligament, as well as to the superficial aspect of that ligament itself. The flexor brevis pollicis, by its outer, *i.e.*, its superficial head, is attached to the trapezium on the inner side of the tendon of the flexor carpi radialis and to the anterior edge, as well as the palmar surface of the annular ligament.

The TRAPEZOID gives origin to the deep or inner part of the *flexor brevis pollicis.*

The OS MAGNUM gives origin to the deep or inner part of the *flexor brevis pollicis.*

The UNCIFORM, by the lower border of its process, gives origin to the *opponens* and *flexor brevis minimi digiti.*

and (2) into the palmar surface of the tubercle and the ridge on the palmar surface of the scaphoid, as well as into the superior and inner angle of the trapezium and the palmar surface of the trapezoid. Between these two sets of outer attachments the tendon of the flexor carpi radialis passes, being covered over by the fibres which reach to the outer points of the bones, and being separated by the inner set from the canal or subway common to the flexor tendons of the fingers, the median nerve, and long flexor of the thumb.

From an examination of these attachments, it will be seen that the various bones of the carpus are not only braced together transversely, but also that the extremities of the wavy line of the *intercarpal* articulation are held together firmly by this anterior annular ligament. Thus the unciform is bound to the base of the pisiform, and, through the anterior fasciculus of the internal lateral ligament, to the styloid process of the ulna; whilst on the radial side, not only are the trapezium and the trapezoid held in union, but these two bones of the second row are braced by strong and numerous fibres to the scaphoid. This compensates for the weakness of parts of the anterior carpal ligament, which consists, as has been described above, for the most part of fibres which bind the os magnum to the three bones of the first row of the carpus, leaving in great degree the trapezium, trapezoid, and unciform to be securely connected with the bones above by means of this anterior annular ligament.

THE ARTERIES.—It would be alike tedious and useless to take each of the carpal articulations separately, and describe in detail the arterial and nerve supplies to them; nor is it possible to enumerate the muscles in connexion with or moving each separate joint, as their action affects several, if not all, the joints simultaneously. It will be sufficient therefore to refer to the arterial, nerve, and muscular supply of these joints collectively. Blood is conveyed to them through—

1. The anterior and posterior carpal branches of the radial artery.
2. The anterior and posterior branches of the ulnar artery.
3. The carpal branch of the anterior interosseous on their palmar aspect.
4. The recurrent carpal branch of the deep palmar arch.
5. The terminal twigs of both the anterior and posterior inter-

osseous on the dorsal aspect of the carpus, which usually inosculate with the posterior carpal branches of the radial and ulnar.

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(1) The posterior interosseous nerve; a branch of the great musculo-spiral trunk, through which, directly or indirectly, all the extensors and supinators of the forearm and hand, as well as the skin over the back of the carpus, metacarpus, and phalanges are supplied. The posterior interosseous terminates on the back of the carpus in a ganglion, from which filaments pass off to the adjoining ligaments and articulations.

(2) The median nerve supplies a few filaments to the radial side of the joint.

(3) The ulnar by its deep branch supplies those on the ulnar side of the third interosseous space.

THE MUSCLES.—Besides the muscles which pass over the front and back of the carpus to reach the phalanges or the bases of the metacarpal bones, there are in connexion with the carpal bones and their ligaments the small muscles of the thumb and little finger. Thus, taking the several bones in order, the following muscles are attachad to them:—

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The UNCIFORM, by the lower border of its process, gives origin to the *opponens* and *flexor brevis minimi digiti.*

The actions of these several muscles are sufficiently indicated by their names. Though arising from the carpal bones and their palmar ligaments, they can in no appreciable sense act upon the carpal or medio-carpal articulations.

THE MOVEMENTS.—Movements of the carpal articulations between bones of the same row are very limited indeed, and consist only of slight gliding one upon the other. Yet these gliding movements, slight as they are, give sufficient elasticity to the carpus to break the jars and shocks which result from blows or falls upon the hand. The movements of one row of bones upon the other, at the medio-carpal articulation, are much more extensive, especially in the direction of flexion and extension, so that the hand enjoys a greater range of these movements than is permitted at the wrist-joint alone. In the wrist-joint extension is more free than flexion, owing to the greater extent of the articular surface upon the dorsal than upon the palmar aspect of the scaphoid, lunar, and cuneiform bones. But this limitation of flexion is compensated for by the greater freedom of flexion than of extension at the medio-carpal joint, and by the flexion permitted at the carpometacarpal joint, so that on the whole the degree of flexion of the hand is greater than that of extension.

Flexion and extension are not the only movements which are permitted at this joint. A slight amount of lateral motion, *i.e.*, abduction and adduction, accompanied with a limited degree of rotation, takes place. This rotation of the hand consists in a rotation of the head of the os magnum, and of the superior and outer angle of the unciform in the socket formed by the three bones of the upper row, and in a gliding forwards and backwards of the trapezium and trapezoid upon the scaphoid.

In addition to the ligaments, the wavy outline of the articular surfaces, and the extent and variety of shape of the apposed facets, render this joint very secure. Thus dislocation of the second row forwards is prevented by the trapezium and trapezoid resting on the posterior, *i.e.*, dorsal aspect of the scaphoid, and by the cuneiform winding forwards towards the anterior side of the inner surface of the unciform; and dislocation of this same row backwards is resisted by the *forward* and downwards inclination of the socket of the scaphoid, lunar, and cuneiform, which receives the os magnum and unciform.

The movements at the medio-carpal joint are produced in separating it from the outer facet. It is convex for a short space posteriorly, concave in chief part and anteriorly; it articulates with the third metacarpal bone. The outer facet is also of large size; it is concave, and inclined a little outwards, and articulates with the second metacarpal bone. The inner facet is not larger than a melon seed, is situated at the dorsal corner of the surface, is inclined a little inwards, and articulates with the fourth metacarpal bone.

The *unciform*, by its inferior surface, articulates with two, viz., the fourth and fifth, metacarpal bones, and for this reason is divided by an antero-posterior ridge into two facets of nearly equal size, each of which is concave from before backwards. The *outer* looks directly downwards, and receives the fourth metacarpal bone; the *inner*, often a little larger than the outer, and convex from side to side, inclines a little inwards to articulate with the fifth metacarpal bone.

The Metacarpal Bones.—The superior or carpal extremity, *i.e.*, the base of each of these bones, has five surfaces, and is expanded. Somewhat cuneiform, it is wider at the dorsum than in front. By its superior surface it articulates with the carpus; its anterior and posterior surfaces are rough and uneven, for the attachment of ligaments; its internal and external surfaces are either free, or facetted to articulate with one another.

The *second metacarpal bone* is at its carpal end prolonged upwards internally, and its terminal or superior surface is divided into three facets for as many carpal bones. The outer is a flat square-shaped surface, situated near the dorsum, and inclined outwards and forwards for the trapezium; the inner is narrow, and inclined inwards for the os magnum; whilst the middle one, the largest, articulates with the trapezoid.

The *third metacarpal bone* is prolonged upwards externally, and sometimes reaches far enough to articulate with the posterior and internal angle of the trapezoid, notwithstanding the second articulates with the os magnum at the palmar aspect and for some distance backwards, towards the dorsum. By its terminal carpal surface it articulates with the middle facet on the inferior surface of the os magnum.

The *fourth metacarpal bone* presents on its terminal carpal surface two very unequal facets; one, situated externally and close to the dorsum, articulates with the minute internal facet on the inferior surface of the os magnum; the other is large, and articulates with the unciform.

The *fifth metacarpal bone* has a nearly square-shaped articular surface, convex from dorsum to palm, and concave from side to side, and directed a little outwards for articulation with the innermost facet on the inferior surface of the unciform.

The line of the carpo-metacarpal joint of the fingers is nearly plane, but has a slight convexity downwards or towards the metacarpus. The base of the second bone, *i.e.*, of the metacarpal of the index-finger, is firmly locked in its position owing to the projection downwards of the inner inferior angle of the trapezium, and upwards of the outer angle of the base of the third metacarpal bone. In this respect it resembles the second metatarsal bone of the foot.

The fifth metacarpal bone is set off at a slight angle from the other three, and like the bone of the thumb (the first) its base is concavo-convex, so that it enjoys the same kind of movements, but more limited in degree. The base of the third bone is also very securely fixed by the upward projection of the outer side of its base into an angle formed by the trapezoid and os magnum.

THE LIGAMENTS.—Dorsal, palmar, and interosseous ligaments connect the bones of the carpus with the metacarpus.

The Dorsal Ligaments.—Three dorsal ligaments pass to the second bone; one from each of the carpal bones, with which it articulates—viz., trapezium, trapezoid, and os magnum. Two dorsal bands pass from the os magnum to the third metacarpal bone. Two dorsal ligaments extend from the fourth metacarpal bone to the carpus—viz., one to the os magnum, and the other to the unciform. Sometimes only a single dorsal ligament attaches this bone to the carpus, and that passes from the unciform. The fifth has a single ligament, and that connects it with the unciform.

The Palmar Ligaments.—A strong ligamentous band connects the second metacarpal bone with the trapezium, internal to the ridge for the annular ligament. It is covered by the sheath of the flexor carpi radialis.

Three ligamentous bands connect the third bone of the metacarpus with the carpus; one extends obliquely outwards to the trapezium, a middle one passes vertically upwards to the os magnum, and an internal band passes over the carpal end of the fourth metacarpal bone and its ligament, and is inserted into the unciform and the fifth metacarpal bone.

One ligament connects the fourth metacarpal bone with the unciform.

One ligament, and that a feeble one, connects the fifth bone with the unciform; fibres extend all around the inner aspect of this articulation from dorsal to palmar surface. It is further strengthened on the palmar aspect by the ligamentous or rather tendinous fibres (flexor carpi ulnaris) prolonged from the pisiform bone to it, and by the strong inner slip of the ligament of the third metacarpal bone; and on the dorsal aspect, by the tendon of the extensor carpi ulnaris.

The Interosseous Ligament.—This is limited to one part of the articulation, and intervenes between the two inner metacarpal bones and the third metacarpal. It consists of short strong fibres, connecting together the contiguous angles of the unciform and os magnum, and the fourth and third metacarpal bones towards their palmar aspect.

Besides the above ligaments, there is a short but thick and strong ligament connecting the edge of the trapezium with the outer border of the base of the second metacarpal bone. It is especially thick immediately below the facet on the trapezium for the second bone. It helps to separate the carpo-metacarpal joint of the thumb from the common carpo-metacarpal articulation, and serves to close in the radial side of the common carpo-metacarpal joint itself.

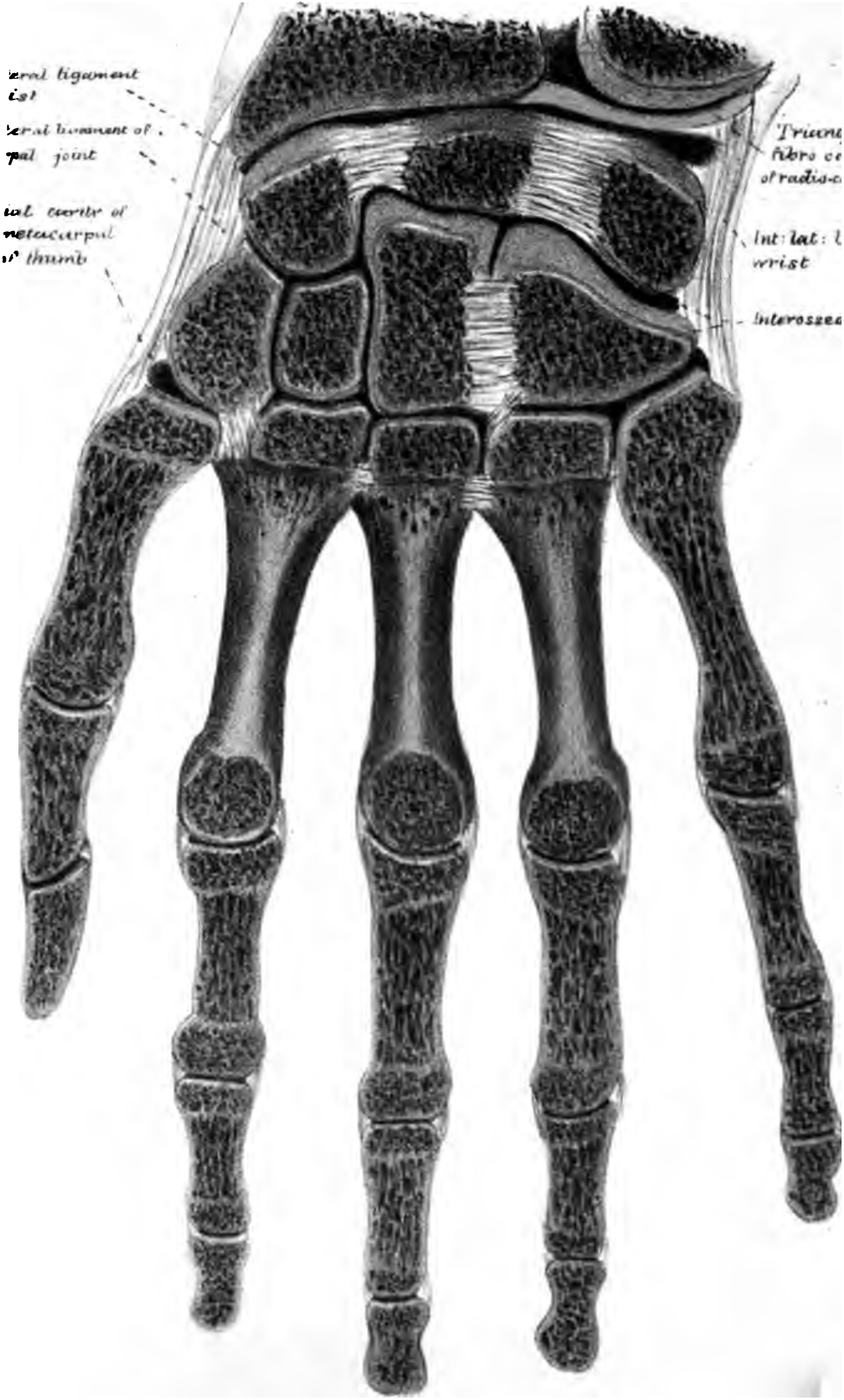
The SYNOVIAL MEMBRANE is a continuation of that of the medio-carpal and small carpal articulations. Occasionally there is a separate membrane for that part of the carpo-metacarpal joint formed by the unciform and the two inner metacarpal bones. The joint between the fourth metacarpal bone and the os magnum is lined by the general synovial membrane. This is important surgically, as it shows the danger to the whole carpal synovial sac of interfering with the base of the fourth bone.

THE MUSCLES.—The muscles in connexion with this articulation, besides the flexors of the fingers which pass over them to their insertion into the phalanges, are the flexors and extensors of the carpus, and the following small muscles of the thumb and little finger:—

1. The deep portion of the flexor brevis pollicis arises partly

CTION SHOWING THE SYNOVIAL CAVITIES OF THE WRIST & HAN

PLATE



Frank Steele del. ad nat

West, Newman & Co lith

from the base of the third metacarpal bone, as well as from the palmar surface of the os magnum and the trapezoid.

2. The adductor pollicis arises from the carpal extremity, as well as from the whole length of the shaft of the third metacarpal bone, on its palmar aspect.

3. The opponens minimi digiti is inserted into the whole length of the palmar aspect of the fifth metacarpal bone.

Both the other small muscles of the little finger, the abductor and flexor brevis minimi digiti, pass over the joint, and indirectly act upon it, though they are not attached to a metacarpal bone. The latter arises from one of the bones of the carpo-metacarpal articulation, viz., the unciform. The abductor arises from the pisiform.

The interossei muscles are also connected with the metacarpus, but have no relation to this articulation.

Of the muscles which have a direct action on the articulation:—

(*a*) The flexor carpi radialis is inserted into the base of the second and third, *i.e.*, metacarpal bones of the index and middle finger,

(*b*) The flexor carpi ulnaris, into the base of the metacarpal bone of the little finger, as well as into the pisiform bone,

(*c*) The extensor carpi radialis longior is inserted into the dorsal aspect of the base of the second metacarpal bone on its radial side,

(*d*) The extensor carpi radialis brevior into the dorsal aspect of the carpal end of the third metacarpal bone on its radial side,

(*e*) The extensor carpi ulnaris into the base of the metacarpal bone of the fifth, or little finger, on its dorsal aspect.

Thus it will be observed that the bone of the ring-finger only is without either flexor or extensor tendon; that the middle finger bone has the short radial extensor, but no flexor; and that the index and little fingers are each provided with both a flexor and extensor muscle. The muscles, though acting most freely upon those parts at which they are attached, yet act upon the whole carpo-metacarpal joint, owing to the intimate union of the bases of the four metacarpal bones with one another. After producing their effect on this joint, they continue in action to move, first the medio-carpal, and second the radio-carpal, articulations. The opponens minimi digiti acts directly on the carpo-metacarpal joint of the little finger, making this finger metacarpal to the palm, just as the opponens pollicis moves the thumb. Owing to the close connexion of the bases of the metacarpal bones it also, by bending the little finger, affects the whole carpo-metacarpal articulation. It increases the hollow of the palm, and assists in forming what is called 'Diogenes drinking-cup.'

THE MOVEMENTS OF THE CARPO-METACARPAL JOINTS.—The portion of the carpo-metacarpal joint formed by the fifth metacarpal and unciform bones approaches in shape and mobility somewhat to the first or thumb carpo-metacarpal joint. It has a greater range of forward and backward movement than the three others, but its lateral motion is nearly as limited as theirs. This part of the joint is protected above in front by the process of the unciform bone, which limits its flexion. The lateral motion towards the ulnar side is checked by the strong palmar ligamentous band which unites it to the base of the third metacarpal bone; and by the strong transverse ligament at the heads of the bones, to be presently described.

The motion of the second and third and fourth metacarpal bones is very limited indeed, especially that of the middle and ring fingers, to which no long flexor muscle is attached. It consists almost entirely of slight forward and backward gliding movements of the metacarpal on the carpal bones, *i.e.*, of flexion and extension. These movements are produced by the same muscles, and in the same way, as the flexion and extension at the medio- and radio-carpal joints, *i.e.*, directly by the muscles inserted into the bases of the metacarpal bones, and indirectly through the muscles inserted into the phalanges. Owing to the close connexion of the bases of the metacarpal bones, the contraction of the flexor and extensor carpi muscles affects the whole carpo-metacarpal articulation by their actions upon the particular bones into which they are inserted.

Abduction and adduction of the four metacarpal bones together may be spoken of in the same way as abduction and adduction of the wrist, *i.e.*, abduction as lateral movement towards the radial side, adduction as lateral movement towards the ulnar side. This is not what is meant by abduction and adduction of the fingers, which is from and to the middle line of the hand through the middle finger.

Abduction is prevented by the locking or impaction of the second bone against the inner surface of the trapezium, and the flexor and extensor carpi radialis restore the. metacarpus after it has been moved towards the ulna, *i.e.*, adducted by the flexor and extensor carpi ulnaris.

Adduction is permitted to a moderate degree, and is favoured by the inward and upward slope given to the unciform and fifth metacarpal bones.

Besides these angular movements, a slight amount of shifting or gliding of the fourth and fifth metacarpal bones takes place at this joint, when the concavity which they present towards the palm is increased, as in deepening the hollow of the hand to form the "cup of Diogenes." This effect is produced by the simultaneous action of the flexor carpi ulnaris and opponens minimi digiti, acting on the fifth bone, whilst the flexor carpi radialis pulls forwards and steadies the radial side of the metacarpus.

The movements necessary for the formation of "Diogenes' cup" are complex, and involve many muscles; for whilst the metacarpus and the first phalanges have to be slightly bent, and the thumb and little and ring fingers arched towards the centre of the hand, the phalanges must be kept extended upon each other in order to make the "cup" complete; the depth of which varies inversely with the flexion of those bones. The interossei and lumbricales, therefore, must be in action. The degree of flexion or extension at the wrist is indifferent to its formation.

The Carpo-metacarpal Joint of the Thumb.

Class, Diarthrosis. *Subdivision*, Arthrodia.

The divergence of the first metacarpal bone from the line of direction of the other four contrasts very strongly with what is found to be the case in the foot, and is the great peculiarity which characterises the hand. When the hand is fully extended, the angle which the thumb forms with the vertical line through the middle finger is between 50° and 55°. To this divergence of the thumb is due the facility of opposing it to each and all the fingers, and the great power of the hand as an organ of prehension and of varied usefulness.

The length of the thumb in man distinguishes his hand from that of the quadrumanous animal, in which the short weak thumb barely reaches to the level of the head of the metacarpal bone of the forefinger.

The chief feature which distinguishes this joint from the other carpo-metacarpal articulations, from which it is quite detached, is its great mobility. In many respects it resembles the sterno-clavicular joint; but there is this difference—that the articular surfaces of the two bones are more equal in size, and more evenly adjusted to one another, and there is no fibro-cartilage separating them. The bones are the trapezium and the first metacarpal.

The *trapezium*, which is situated to the radial side, and projects a little in advance of the other bones in the second row of the carpus, presents on its external and inferior aspect a large articular surface for the metacarpal bone of the thumb. This facet is oval in shape, with its long axis obliquely transverse, in which direction it is concave; from before backwards it is convex.

The *first metacarpal bone* is the shortest and thickest of all, is placed on a plane anterior to the other four, and is so inclined that its palmar surface looks somewhat inwards towards the median line of the hand. Owing to its divergence from the other four bones, the space between it and the second metacarpal bone is larger and more distinctly triangular. Its carpal extremity has not the wedge shape of the succeeding three bones, and is rather wider on the palmar than the dorsal aspect. Its articular facet for the trapezium occupies the whole of its superior terminal surface, and is concave from behind forwards, and convex from side to side, just the converse of the facet on the trapezium to which it is adapted, and on which it moves freely. It has no lateral articular facets, being separated by a distinct interval from the base of the second metacarpal bone; but on its outer side it presents a rough tubercle nearer the palmar than the dorsal aspect for the insertion of the extensor ossis metacarpi pollicis.

THE LIGAMENTS.—The ligamentous apparatus of this joint consists of a capsule, the fibres of which are thicker and more numerous in the situations at which there is the greatest strain. The bundles or bands of fibres of which this capsule is formed pass from the trapezium around the margin of the saddle-shaped articular facet for the thumb to the sides, dorsum, and palmar surface of the carpal end of the first metacarpal bone. They are stronger upon the dorsal than on the palmar surface, for here the joint is less protected by muscles than elsewhere. They are not tense enough to hold the bones in close contact, so that whilst they restrict they do not prevent motion in any direction. Some anatomists have described this capsule as made up of four separate ligaments—viz., *dorsal*, *palmar*, and *external* and *internal lateral*—but this is quite unnecessary. It is sufficient to observe that the dorsal band is stronger than the palmar, and limits flexion (in this conclusion I agree with Weitbrecht, and dissent from Cruveilhier) whilst the palmar limits extension; that the internal lateral is stronger than the external to limit abduction, whilst the external lateral ligament limits adduction of the thumb.

The SYNOVIAL MEMBRANE of this joint is lax, like the capsule, and is quite distinct from the general synovial membrane of the carpal and carpo-metacarpal articulations.

THE MUSCLES.—There are several muscles to be considered as acting on this joint, and yet only three are attached to the first metacarpal bone; these are the (1) extensor ossis metacarpi pollicis, inserted into the outer or radial side of its base. (2) The opponens (or flexor ossis metacarpi) pollicis, inserted into the whole length of the metacarpal bone on its radial side; and (3) the abductor indicis, which arises from the upper half of the ulnar border of the first metacarpal bone, and from the os trapezium.

The trapezium gives origin to the abductor and opponens and flexor brevis pollicis, as well as to the abductor indicis. All the muscles, however, which are attached to the phalanges of the thumb move also the metacarpal bone; for it is a rule, that in proportion to the number of joints that a muscle passes over, its offices must be more numerous; thus, *e.g.*, the flexor profundus digitorum not only moves the third phalanx on the second, the second on the first, and these again on the metacarpal bone, but it likewise flexes the carpo-metacarpal, medio-carpal, and radio-carpal articulations; whilst the flexor sublimis, which bends the second joint of the finger on the first, and the first on the metacarpal bone, flexes all the other transverse carpal joints, including the wrist, and even bends the forearm on the arm at the elbow.

Bearing this law in mind then, and remembering that a muscle acts primarily upon the joint formed by the bone into which it is inserted, and secondarily upon the joints above it, *i.e.*, nearer to its origin, we may group the muscles which act upon the carpo-metacarpal joint of the thumb as flexors, extensors, abductors, and adductors.

Flexors.—The opponens (flexor ossis metacarpi) pollicis acts directly upon the metacarpal bone, drawing it forwards at the same time that it abducts.

The flexor brevis pollicis acts directly on the first phalanx, to draw it towards the palm.

The flexor longus pollicis acts primarily upon the terminal phalanx.

The abductor pollicis acts primarily upon the first phalanx.

The adductor pollicis acts primarily upon the first phalanx, and adducts while it flexes.

Extensors.—The extensor ossis metacarpi pollicis acts directly upon the metacarpal bone, and abducts chiefly, though it extends, *i.e.*, draws backwards, the bone at the same time.

The extensor primi internodii pollicis acts, as its name indicates, primarily on the first phalanx, and abducts at the same time it draws backwards the thumb.

The extensor secundi internodii pollicis acts primarily on the terminal phalanx, and is an adductor as well as an extensor.

Abductors.—The extensor ossis metacarpi pollicis, the extensor primi internodii pollicis, abduct and draw backwards at the same time. The abductor and opponens pollicis abduct and draw forwards at the same time.

Adductors.—The adductor and inner portion of the flexor brevis pollicis adduct and draw forwards at the same time. The abductor indicis, when its action on the index-finger is prevented, adducts the thumb by pulling on the metacarpal bone. The extensor secundi internodii pollicis is also an adductor.

THE MOVEMENTS.—The motion of this joint is regulated by the shape of the articular surfaces of the trapezium and first metacarpal bone more than by its ligaments. It consists of flexion, extension, abduction, and adduction, *i.e.*, of forward, backward, outward, and inward movements respectively, and of circumduction, but no rotation. In flexion and extension the metacarpal bone slides to and fro upon the trapezium; in abduction and adduction it glides from side to side, or, more correctly, revolves upon the antero-posterior axis of the joint.

The thumb can be drawn away from the fingers both when they are flexed upon the palm and when they are extended widely open. It can be brought into contact with the tip of each one singly, or with the tips of all collectively. It can be made to touch any part of the palmar or radial surfaces of any of the fingers separately, and can be brought down firmly upon the dorsal aspect of the first, second, or third when flexed, as in the formation of the fist. The power of opposing the thumb to any of the fingers is due to the forward and inward obliquity of its movement of flexion, which is by far the most extensive movement of the thumb. The motion of adduction is limited on account of the proximity of the second metacarpal bone; that of abduction is very free. The movement of the trapezium upon the rest of the carpus somewhat increases the range of all the movements of the thumb.

The Union of the Metacarpal Bones with one another.

Class, Diarthrosis. *Subdivision*, Arthrodia.

The metacarpal bone of the thumb is not connected with any other metacarpal bone. Those of the index, middle, ring, and little fingers are in actual contact at their bases, and the joints between them are furnished with small prolongations of the common or general synovial membrane of the carpus. They are held closely and firmly together by dorsal, palmar, and interosseous ligaments, which pass transversely from one bone to the other, so as to form them into one continuous surface which articulates with the carpus at the carpo-metacarpal joint. A transverse ligament binds together their inferior extremities, or heads.

THE BONES.—The *second metacarpal bone* has upon the inner surface of its carpal end two flat facets, placed one before the other to articulate with corresponding surfaces on the third metacarpal bone.

The *third bone* has upon each of the lateral surfaces of its carpal end two little facets—one near the dorsum, the other near the palmar aspect, and separated by a deep groove (that on the inner side being the deeper) to articulate with similar facets on the adjacent bones. Sometimes these two small facets on one or both lateral surfaces are run together, so as to form but a single facet for the adjacent bone.

The *fourth bone* presents on its outer surface two oval facets, separated by a deep narrow groove; and on its inner aspect a semicircular and slightly concave articular facet for the fifth metacarpal bone.

The *fifth bone* has on its outer lateral surface a narrow semicircular convex articular facet for the fourth bone; and on its inner lateral surface a tubercle for the attachment of the extensor carpi ulnaris.

THE LIGAMENTS.—The *dorsal ligaments* are layers of variable thickness of strong short fibres, which pass transversely from bone to bone. They fill up the irregularities on the dorsal surface of the carpal ends of these bones, and the fibres are therefore more numerous opposite the depressions and little hollows on the bones.

The *palmar ligaments* are transverse layers of ligamentous tissue passing from bone to bone. They cannot be well defined from the other ligaments and fibrous tissue covering the palmar surface of the bones.

The *interosseous ligaments* pass between the apposed surfaces of adjacent bones, and are attached on the distal side of the lateral articular facets of each bone, so as to close in the synovial cavities on this aspect. Where there are two articular facets on one side, the fibres of this ligament extend upwards in the interval between them, so as to connect the bones nearly as far as their carpal terminal surfaces. The interosseous ligament between the fourth and fifth bones is weaker than the rest, and is nothing more than a fibrous covering to the synovial membrane on its lower aspect.

Connexion of the Heads of the Metacarpal Bones.

The digital extremities of the metacarpal bones are connected together on their palmar aspect by what is called the transverse ligament. This consists of three short narrow bands of fibrous tissue, one uniting the ulnar side of the second bone with the radial side of the third, another uniting the ulnar side of the third with the radial side of the fourth, and the third passing between the ulnar side of the fourth and the radial side of the fifth. They are each rather more than a quarter of an inch in depth, and rather less in width from side to side. They limit the distance to which the metacarpal bones can be separated in such actions as grasping, or in the spreading out of the hand, as when the weight of the trunk is borne upon it. They do not limit the range of separation of the fingers, which depends on the degree of lateral movement permitted at the metacarpo-phalangeal joints. The bands are continuous above with the fascia covering over the interosseous muscles, and are connected below with the areolar tissue beneath the skin of the web of the hand. They are on a level with the front surfaces of the bones, and are blended with the other structures at the sides of the metacarpo-phalangeal joints, viz., with the edge of the fibro-cartilage in front and the lateral ligament at the sides of the joint, and with the sheath of the tendons where it springs from the line of union of the fibro-cartilage with the lateral ligament. Over the front of each band a lumbrical muscle passes to its insertion, and the digital nerves and arteries travel on to their destination. Behind each band the interosseous muscles of the corresponding space pass to their insertion. The bands are not in direct relation with the flexor tendons of the fingers; for as the tendons pass over the front of the joints while these transverse bands of ligament are blended along the line of union of the fibro-cartilage and lateral ligament, they are consequently in the interspaces between the tendons. There is no transverse band connected with the thumb. The adductor and flexor brevis pollicis and the ligaments of the carpo-metacarpal joint set the limits to the range of abduction enjoyed by the thumb.

The Metacarpo-phalangeal Joints of the Fingers.

Class, Diarthrosis. *Subdivision*, Ginglymus.

The metacarpo-phalangeal joint of the thumb differs slightly from that of the fingers, and will therefore be separately described. Those of the fingers resemble one another.

The first phalanx is articulated with the head of a metacarpal bone, and united to it by means of three ligaments.

THE BONES.—*The Metacarpal Bone.*—The head or inferior extremity of each of the metacarpal bones is convex from side to side and from before backwards; smooth, and in the recent state covered with cartilage, for articulation with the base of the first phalanx. This articular surface extends much further on the flexor, *i.e.*, palmar aspect, than on the dorsal. On each lateral surface is a deep depression bounded towards the dorsum by a small tubercle. To both tubercle and depression the lateral ligament is attached. The dorsal surface is smooth and flat. The anterior surface presents two little tubercles, between which the head is slightly excavated, and along this concavity the flexor tendons pass. The antero-posterior diameter of the head is larger than the transverse.

The Phalanx of the First Row.—Each of these bones presents at its base, *i.e.*, upper end, a shallow articular concavity with which the rounded head of the metacarpal bone articulates. This concavity is not nearly deep enough for the head of the metacarpal to be received into it, but it is made deeper in the recent state by a glenoid ligament which is very firmly attached to the anterior border of this oval-shaped facet. Its transverse diameter is greater than the antero-posterior—the reverse being the case with the metacarpal bone, and hence the great extent of lateral motion allowed by the joints.

THE LIGAMENTS.—These bones are connected by two strong lateral ligaments and by an anterior fibro-cartilage; whilst posteriorly the joint is covered in by the expansion of the extensor tendon, and by some loose areolar tissue passing from the under surface of the tendon to the bone. Each joint has its own synovial membrane.

The Glenoid Ligament.—The anterior fibro-cartilaginous plate was called by Cruveilhier the glenoid ligament, as it seems more intended to increase the depth of the phalangeal articular facet than to unite the two bones together. It is much more firmly attached to the margin of the phalanx than to the metacarpal bone. Indeed, it is only very loosely connected to the palmar surface of the latter by some lax areolar tissue which covers over the synovial sac, which here is prolonged some little distance upon the shaft of the bone. Laterally, it is intimately blended with the lateral ligaments as well as with the transverse bands connecting the heads of the metacarpal bones with one another. Like the sesamoid bones at the corresponding joint of the thumb, whose place it takes in the fingers, it serves to prevent backward dislocation; but when dislocation does occur, it increases the difficulty of reduction, for owing to its much firmer connexion with the phalanx it follows it backwards behind the head of the metacarpal bone. A sesamoid bone occasionally exists at the inner border of the joint of the little finger.

The Lateral Ligaments.—These are very strong, and firmly bind together the ends of the bones. Each is attached above to the lateral tubercle near the dorsum, and to the depression in front of the tubercle of the metacarpal bone. From this the fibres pass forwards as they descend, and spread out widely on the side of the base of the phalanx. Their anterior fibres are connected with the fibro-cartilaginous plate, and their posterior fibres blend with the tendinous expansion at the back of the joint.

The SYNOVIAL MEMBRANE lines the joint, and forms a loose capacious sac, more especially over the head of the metacarpal bone in front, and the base of the phalanx behind. It is protected on the sides by the lateral ligaments; in front, by the cartilaginous plate, and by some loose cellular tissue attaching the plate to the palmar surface of the metacarpal bone; and behind, by the expansion of the extensor tendon, and by very loose tissue holding the tendon down to the bone above and below the joint.

ARTERIES.—Little branches of arteries penetrate the tissues around the joint, and reach the synovial membrane. They come from the superficial digital branches, as well as from the anterior interosseous vessels which lie upon the front of the interosseous muscles. Arterial arches are sometimes formed on the ends of the bones by the anastomoses of the minute vessels of the two sides.

NERVES.—These are derived from the cutaneous digital branches, or from the small branches for the interosseous muscles.

MUSCLES.—The muscles in connexion with the metacarpo-phalangeal joints are, (1) the superficial and deep tendons which pass over the concave anterior surface of the fibro-cartilaginous plates in front of the joint. The sheaths of these tendons are attached laterally to the margins of the plates, and to the lateral and transverse ligaments where they meet together. (2) The interosseous muscles pass behind the transverse ligament, partly to be inserted into the side of the base of the first phalanx, and partly into the expansion of the extensor tendon. (3) The lumbrical muscles pass over the front of the transverse bands to their insertion into the radial side of the expansion of the extensor tendon at the base of the metacarpal phalanx. (4) The tendon of the long extensor muscles.

The four lumbricales and the seven interossei muscles have each a double action, for while they bend the first phalanx on the metacarpal bone, they at the same time extend the second and third phalanges on the first and second. The lumbricales do this by passing over the front of the transverse ligament to their insertion into the tendinous expansion; and the interossei by having some fibres inserted directly into the side of the base of the first phalanx, which therefore act directly upon it, while others blend with the tendinous expansion.

Bearing in mind then the statement made above, that if a muscle passes over a joint part of its office is to act upon that joint, we may group the muscles of the metacarpo-phalangeal joints into:—*Flexors:* The long flexors (deep and superficial) *i.e.*, flexor sublimis and profundus digitorum; the lumbricales; and the interossei and flexor brevis minimi digiti. *Extensors:* The extensor communis digitorum, extensor indicis, and extensor minimi digiti.

Abductors.—The four dorsal interossei abduct the index, middle, and ring fingers; the abductor minimi digiti acts on the little finger.

Adductors.—The three palmar interossei are adductors of the index, fourth, and little fingers.

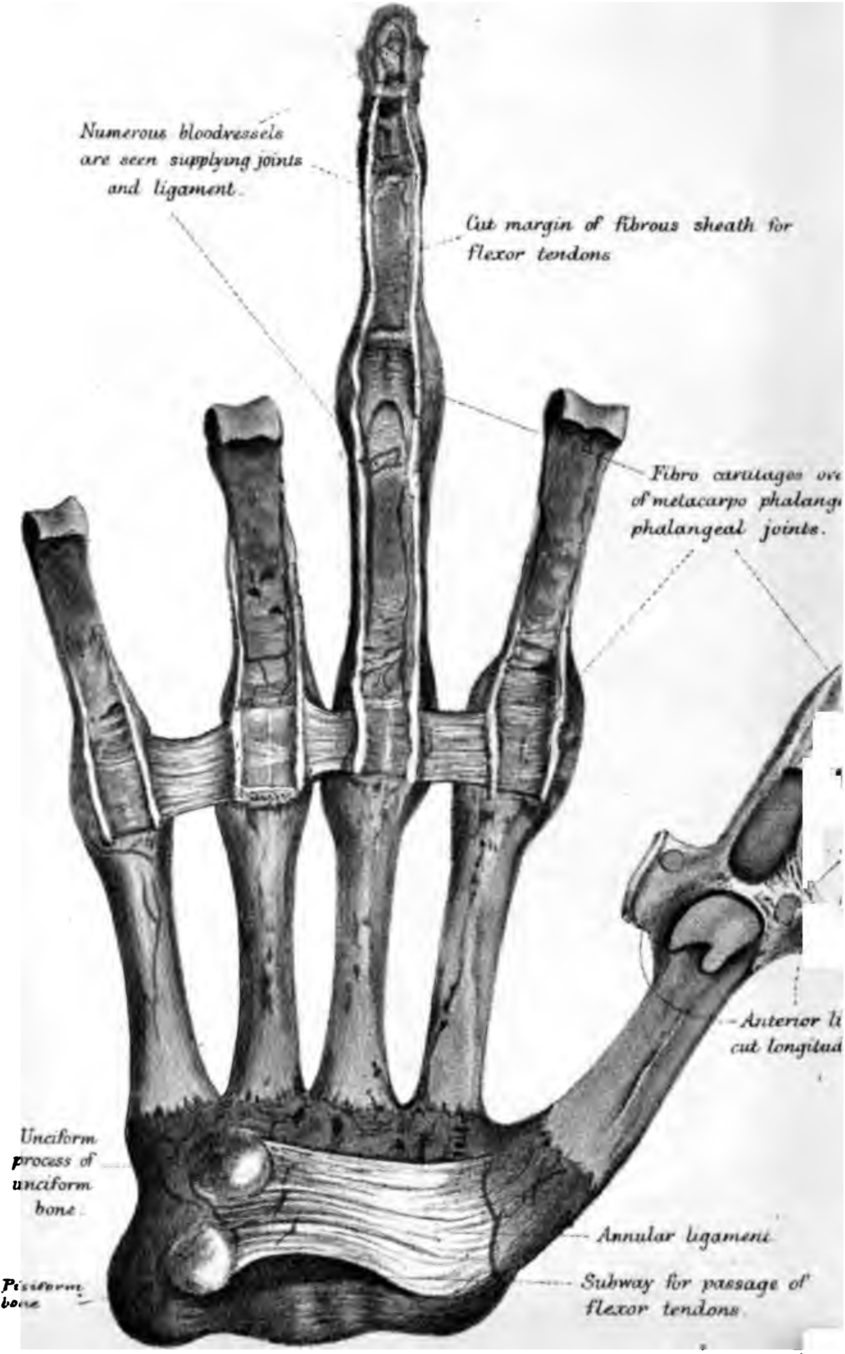
THE MOVEMENTS.—Flexion, extension, abduction, and adduction, and the combination of these—viz., circumduction—are all permitted at these joints.

Flexion is the freest movement, and may be continued until the phalanx is at a right angle with the metacarpal bone. It is on this account that the articular surface of the head of the metacarpal bone is prolonged so much further on the palmar aspect, and that the synovial sac is here so ample and loose.

Extension is the most limited of the movements, and can only be carried to a little beyond the straight line. Abduction and adduction are pretty free, but not so free as flexion. As a rule, although these movements can be executed separately, flexion is associated with adduction, and extension with abduction. This may be proved by simply opening the hand, when the fingers involuntarily separate a little from one another as they become extended; so they as naturally close together in bending the fingers on the palm.

Circumduction being composed of the four angular movements, its degree of freedom depends upon the range of these several movements individually. Doubtless the abduction and adduction and circumduction enjoyed by these joints is due to the long axis of the articular facets of the two bones of the

JOINTS OF THE FINGERS & THUMB SEEN FROM THE PALMAR. SURFACE.


Numerous bloodvessels are seen supplying joints and ligament.
Cut margin of fibrous sheath for flexor tendons
Fibro cartilages ov
of metacarpo phalang
phalangeal joints.
Anterior li
cut longitud
Unciform process of unciform bone.
Annular ligament
Pisiform bone
Subway for passage of flexor tendons

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joint being at right angles to one another, so that from the shape of the bone the joint assumes almost an enarthrodial character. The anterior fibro-cartilage, it is true, increases the cup-like articular facet of the phalanx which plays upon the rounded head of the metacarpal bone; and for this reason it was called glenoid; but the very firm connexion of the cartilage with the phalanx and its loose attachment to the metacarpal bone, increase the hinge-like nature of the articulation, and suggest to our mind the olecranon process of the ulna in the security it affords against dislocation, and the purpose it serves in keeping the moving surfaces of the bones in due relation to one another. If there were permitted at these joints any appreciable amount of rotation round the long axis of the digits, they would be properly described as the ball-and-socket joints, notwithstanding that the bone which forms the "socket" moves upon the bone which presents the "ball." Some anatomists indeed have spoken of the metacarpo-phalangeal joints as enarthroses.

The Metacarpo-phalangeal Joint of the Thumb.

Class, Diarthrosis. *Subdivision*, Ginglymus.

THE METACARPAL BONE.—The inferior extremity of the metacarpal bone of the thumb differs very materially from the corresponding ends of the metacarpal bones of the fingers. Its terminal and articular surface is less convex, especially in the transverse direction; its widest measurement is from side to side instead of from before backwards; the edge of the articular surface is raised, and irregular on the palmar aspect, and there is on each side of this aspect of the facet a little smooth surface for the sesamoid bones, which take the place of the fibro-cartilage found on the front of the articulations of the fingers. The depressions on the lateral surfaces are well-marked, but not so deep as those on the corresponding bones of the fingers, and they do not encroach so much upon the articular facet.

THE FIRST PHALANX OF THE THUMB.—The base of this bone resembles more the base of the second than that of the first phalanx of the fingers, so that the anterior edge of its articular surface is prolonged a little in the centre, so as to form a little process which intervenes between the sesamoid bones, and prevents any lateral motion, more especially during flexion.

THE LIGAMENTS.—In place of a plate of fibro-cartilage there are in this joint two small sesamoid bones, enveloped in ligamentous fibres on all sides, excepting that which faces towards the interior of the joint. The lateral ligaments resemble the corresponding ligaments in the joints of the fingers, and posteriorly the capsule is completed by some ligamentous fibres passing between them.

The Sesamoid Bones.—These are situated one on each side of the middle line of the palmar surface of the thumb. On their sides which do not face one another they are connected with the anterior fibres of the lateral ligament, some of which are inserted into them. On the sides facing one another, they are connected together by some very strong thick fibres having a transverse direction, and over the front aspect of which the flexor tendon plays. Above, they, as well as their transverse connecting fibres, are connected with the front of the metacarpal bone; and below some very strong but short fibres pass off from these to the front of the base of the phalanx. Anteriorly they give attachment to the tendons of the short muscles of the thumb, and over their surface the various ligamentous fibres blend. Posteriorly they are smooth and facetted to play upon the little articular tubercles which are prolonged upwards on the palmar surface of the head of the metacarpal bone. They provide a shifting leverage for the tendons of the flexor brevis pollicis muscle by increasing their angle of insertion into the sides of the base of the first phalanx.

The Lateral Ligaments.—A short strong band of fibres radiates from the depression on each side of the head of the metacarpal bone to the same side of the base of the phalanx, and to the sesamoid bone. As they descend, the fibres pass a little forwards, so that the greater number of them are inserted in front of the centre of motion. They keep the joint firm and steady, and together with the shape of the articular surfaces of bone prevent lateral motion.

The Posterior Ligament.—Passing from the lateral ligament on one side to that on the other, across the back of the joint, are some scattered fibres which serve to protect the synovial sac, and to complete the capsule of the articulation.

ARTERIES.—The joint is supplied by fine capillaries and arteries, which penetrate the ligamentous tissue, and reach the synovial sheath. They are derived from the branches of the radial artery which supply the soft structures of the thumb.

NERVES.—Filaments are given to the joint from the branches of the median and radial nerves which supply the skin of the thumb, and from the branches of the ulnar which supply the adductor and inner part of the flexor brevis pollicis.

THE MUSCLES.—The flexor longus pollicis, the flexor brevis pollicis, the abductor and adductor pollicis, and the extensor primi and secundi internodii pollicis, all act upon this articulation of the thumb.

The action of these muscles is sufficiently explained by their names, and it is therefore unnecessary to group or describe them further.

THE MOVEMENTS.—This is more strictly a hinge-joint than the corresponding articulations of the fingers. Flexion and extension are the two chief movements. Very little lateral movement, or abduction and adduction, is permitted, and that little only when the joint is slightly bent. The abductor and adductor pollicis, pulling upon the base of the first phalanx of the thumb, effect movement at the carpo-metacarpal articulation, and act scarcely at all upon the metacarpo-phalangeal. It is in consequence of the free play of the metacarpal bone of the thumb at the carpus that there is so little lateral movement requisite here, so that we see what the thumb gains at the carpal end of its metacarpal bone it loses at its phalangeal extremity; and *vice versâ*, what the fingers lack at the carpus is made up to them at the metacarpo-phalangeal joints, but not sufficiently to give them the same free and extensive movements possessed by the thumb. The similarity between the motions of the thumb upon the carpus, and of the phalanges of the fingers upon their own metacarpal bones, has been assigned as one of the reasons for considering the thumb to be composed of three phalanges, which are immediately connected with the carpus, *i.e.*, without the interposition of a metacarpal bone.

The Inter-phalangeal Articulations.

Class, Diarthrosis. *Subdivision*, Ginglymus.

THE BONES.—The *phalanges of the first and second rows* present at their *inferior* extremities a smooth trochlear surface, consisting of two lateral convexities separated by a shallow concave articular interspace. The articular surface is prolonged further on the palmar than on the dorsal aspect; and whereas it is broad and extends across the whole width of the front, it is much narrower on the back of the bone. On the sides of this extremity there are well-marked rough depressions for the attachment of the lateral ligaments.

The *phalanges of the second and third rows* present at their *superior* extremities an articular surface, which is broader from side to side than from before backwards, and which is divided into two lateral concave smooth facets by an articular ridge, which extends from the posterior to the anterior border of the articular surface. Thus these terminal facets at the superior extremities of the bones of the second and third row are adapted to fit on to the trochlear surface at the inferior extremities of the bones of the first and second row. The lateral surface of the superior end of the second and third phalanges is not excavated, but instead presents a prominent rough border which gives attachment to the lateral ligaments.

THE LIGAMENTS.—The phalanges of each finger and of the thumb are bound together respectively end to end by means of an anterior flattened plate of fibro-cartilage, by two lateral ligaments and by the expansion of the extensor tendon. Other ligamentous fibres pass between the phalanges and the skin.

The Fibro-cartilage, or Glenoid Ligament.—This is sometimes spoken of as the "sesamoid body," from its taking the place of and serving the same purposes (viz., giving leverage to tendons, and preventing posterior dislocation of the phalanx to which it is united) as, the sesamoid bones at the metacarpal phalangeal joint of the thumb. It resembles in position, connexion, and uses the fibro-cartilage of the metacarpo-phalangeal joints of the fingers. Like it, it is but slightly connected (by means of fibro-areolar tissue) with the bone on the proximal side of the joint, which it helps to construct, but very firmly with the bone on the distal side. It blends with the lateral ligaments of the joint. Over it passes the flexor tendons, and to its edges are connected the lateral boundaries of the sheaths of the tendons. Occasionally a sesamoid bone is developed in the cartilage of the inter-phalangeal joint of the thumb, but seldom, if ever, in those of the joints of the fingers.

The *lateral ligaments* are strong bands which are attached above to the rough depressions on the sides of the upper phalanx and to the projecting lateral margins of the lower phalanx of each joint, as well as into the edges of the fibro-cartilaginous plate. They are tense in every position of the joint, and entirely prevent any lateral motion.

Posteriorly, they are connected with the lateral expansion of the extensor tendon, which covers in the joint behind. Passing between the deep surface of the extensor tendon and the bone above and below the joint, is a little white fibro-areolar tissue which thickens the synovial sac posteriorly, and completes the capsule where the tendon, by passing onwards, would otherwise leave it imperfect.

Cutaneo-phalangeal Ligaments.—Strong ligamentous fibres, first described I believe by Professor Cleland, extend from the sides of the phalanges near their articulations and are inserted into the skin about the joints, more especially into the thicker and wrinkled skin of their dorsal aspect. These ligaments retain in its place the integument at the back and sides of the joints during flexion. They are present about the joints of the thumb as well as of the fingers. Though seen at the distal joints, they are best developed at the first inter-phalangeal articulations of the fingers. The fibres are attached to the lateral ridges of both the phalanges of a joint and decussate—some passing upwards and others downwards—as they proceed, behind the digital artery and nerve, before spreading out into the skin on both palmar and dorsal aspects.

The SYNOVIAL MEMBRANE of each of these joints is ample and loose, and extends upwards a little way along the shaft of the proximal bone. It is very thinly covered above the upper margin of the fibro-cartilaginous plate.

THE ARTERIES.—Blood is freely supplied to these joints by little vessels, which after coming off from the digital arteries run along in the sheaths of the tendons, one on each side. These little vessels anastomose beneath the tendons at both ends of each phalanx, and send branches through the fibrous tissue to the synovial lining of the joint. These vessels are very constant and uniform in their arrangement and distribution.

THE NERVES are supplied from the digital branches of the corresponding fingers.

THE MUSCLES.—Over the joints between the first and second rows of phalanges there pass the tendons of the muscles which are inserted into the terminal phalanges, as well as those which are inserted into the second phalanges. Their actions are sufficiently explained by their names, and by what has gone before. It will be sufficient here to enumerate them according to their mode of insertion. Thus, into the rough lateral borders of the second phalanx of the fingers near its base is inserted the divided tendon of the flexor sublimis digitorum—flexor perforatus; and into the posterior surface of the base of the same bone the central slip of the extensor communis digitorum.

The thumb is usually spoken of as being deficient in the *second* phalanx.

Again, into the anterior surface of the terminal phalanx of the thumb the flexor longus pollicis is fixed; into the posterior surface the extensor secundi internodii pollicis is inserted. Into the anterior surface of the corresponding phalanx of each of the fingers the flexor digitorum profundus, the flexor perforans, is inserted; and into the dorsal surface the conjoined lateral slips of the extensor communis digitorum tendon. Nearer the carpus this tendon divides into three parts, the central of which gets attached to the base of the second phalanx, whilst the other two pass on, reunite, and are fixed to the base of the last phalanx. The lumbricales and interossei muscles blend with the extensor tendon and extend the second and third phalanges.

THE MOVEMENTS.—Flexion and extension are the only movements possible at these joints. Flexion is much more free than extension, and can be continued till the one bone is at right angles to the other. The second phalanx can be flexed through from 110° to 115° upon the first, when the first is not flexed upon the metacarpal bone. Extension is checked when the finger is straight, *i.e.*, it cannot go beyond a right line.

The great freedom of flexion is due to the forward slope and the greater anterior extent of the articular facet of the inferior ends of the bones, and to the direction of the fibres of the lateral ligaments which pass a little forwards to their insertion into the distal bone.

It is interesting to remark that at the metacarpo-phalangeal articulation, and at each of the inter-phalangeal, the extreme of flexion is reached when the distal bone has been brought to a right angle with the one next immediately above it; and as we have four bones and three joints for each finger, when the hand is closed, the several bones of each finger form a four-sided figure, whose opposite sides are parallel, and at right angles with the other two; thus the metacarpal bone and the second phalanx are parallel with each other, and at right angles to both the first and third phalanges: similarly the first and third phalanges are parallel with one another.

PART IV.

THE LOWER LIMB.

CHAPTER XVI.

THE HIP-JOINT.

Class, Diarthrosis. *Subdivision*, Enarthrodia.

THE bones which enter into the formation of this joint are the innominate and the femur; the former at its acetabular part, the latter by its head and neck.

ACETABULUM is a deep hemispherical recess on the outer surface of the os innominatum, at the spot where the three component parts of that bone unite. The ilium forms a little less than two-fifths, the ischium a little more than two-fifths, while the pubis completes the remaining one-fifth of the cup-shaped cavity.

In the dry bone it forms between 170 and 175 degrees of a circle; but in the recent state it is deepened, and its orifice is contracted by the fibro-cartilaginous rim, called the cotyloid ligament.

Its diameter varies in different cases, but in the adult bone is usually between two and two and a half inches.

Its direction is downwards, outwards, and forwards, so that it receives the head of the femur obliquely.

At its deepest part the bone is so thin that it transmits light; but the upper and posterior wall is formed by the thickest and strongest part of the os innominatum, and is capable of bearing great weight and resisting immense force.

The margin of the cavity reaches from the obturator foramen in front and below, to the constricted part of the ilium above and behind; and from the pectineal eminence above and in front, to the groove above the tuber ischii below and behind. Adjacent to the obturator foramen there is a notch, nearly an inch wide, in the rim of the cavity, converted into a foramen by the transverse ligament; this notch is nearly at the lowest part of the margin, so that the bone is seen very nearly as in the natural position in the body, when held with it downwards.

Between the pectineal eminence and the anterior inferior spine of the ilium, there is an indentation in the rim which marks the place of union of the iliac and pubic portions, and over it passes the ilio-psoas muscle.

Between the middle of the sciatic notch and the rim of the acetabulum is a slightly marked transverse ridge, showing the line of union of the ischium and ilium, which at the anterior extremity forms often a slight thickening and elevation of the acetabular rim.

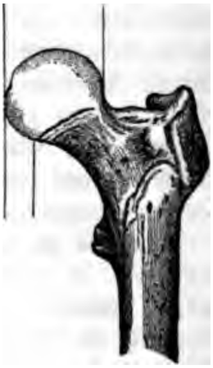
The outer surface of the margin slopes towards the free edge, where it is rounded off. It is rough and uneven, and gives attachment to the capsular ligament, and above to the long tendon of the rectus. The inner edge of the margin where it meets the external is sharply defined.

The acetabulum is partly articular, partly non-articular. The articular portion is of horseshoe shape, and extends inwards from the margin, more or less. It is altogether deficient at the cotyloid notch, which corresponds with the gap of the horseshoe. It is the widest at the iliac part, where it is over one inch from without inwards; then it very gradually gets narrower along the ischium, but widens out again at the ischial end of the cotyloid notch; forwards from the pubo-iliac suture it narrows more rapidly, and does not extend quite up to the pubic end of the cotyloid notch. At its narrowest point in an adult bone it measures half an inch in width. When coated with cartilage, and fringed round with the cotyloid ligament, it fits very closely upon the head of the femur, so as entirely to exclude air from between the apposed surfaces of the bones; and thus the joint derives support from without to the full extent of the pressure of the atmosphere.

The non-articular part extends from the cotyloid notch as a rough recess in the floor of the acetabulum, and corresponds to the area enclosed by the horseshoe. It varies in form and size, but is generally quadrilateral, with its longer axis directed upwards and somewhat backwards from the cotyloid notch; following the curve of the bone it measures two inches in this direction, and about an inch and three-quarters transversely. The anterior superior angle of the recess is the highest point, and is situated above and in front of the mid-spot of the cotyloid notch; the posterior superior angle is near the line of union of the ilium and ischium, or a little below it. The recess widens as it passes upwards; it gives lodgment to a quantity of fatty tissue, with which, however, it is but slightly connected, and is the area over which the ligamentum teres plays, although in some cases it is certainly too extensive to allow the ligament to reach its upper limits.

The inner or pelvic surface of the innominate bone, where it corresponds to the floor of the acetabulum, presents a triangular smooth plane, from which, as well as from the obturator membrane, the internal obturator muscle arises. Thus the floor of the acetabulum forms also part of the wall of the true pelvis by a surface which looks upwards and inwards, and in its posterior extent forwards. It is occasionally perforated in disease of the hip-joint. In some few cases it has no doubt given rise to the idea of stone in the bladder—an error which is to be accounted for by the pelvis being small, or laterally contracted, and the sound in consequence striking upon it here.

DIAGRAM V.



FEMUR.—*The head* of this bone forms two-thirds of a sphere, the circumference of which at its base, *i.e.*, where it joins the neck, varies in different specimens from something less than six inches to six inches and a half. It is very smooth, being covered by articular cartilage, but the articular surface is unevenly distributed, being much greater above the horizontal plane through its centre than below it. If a vertical line be drawn so as to skirt the prominent inner side of the head, the articular surface above the point of contact extends outwards from this line about an inch and two-thirds, but below it only about three-eighths of an inch. The head bulges a little at a spot below the dimple for the round ligament, otherwise it forms part of a true sphere; the part above the dimple recedes outwards, the part below projects inwards a little. This construction of the head, together with the direction of the neck of the bone, and the direction of the acetabulum, as well as the notch in the margin of the acetabulum, are features which facilitate dislocation of the thigh in positions of *ab*-duction.

The articular surface, where the head is passing into the neck of the bone, is limited by a sinuous, not an even outline. This sinuous outline only imperfectly corresponds to the limits of the movements of the head of the bone; for when these are carried to an extreme degree it passes within the margin of the acetabulum. A little below the level of the anterior and upper angle of the great trochanter, the articular cartilage is prolonged further outwards than elsewhere. The position of the fossa for the ligamentum teres is just below and behind the middle point of the articular surface. If two lines be drawn at right angles to one another, the one vertically and the other horizontally, across the middle point, the pit is seen near this point in the lower and posterior quarter. The form of the fossa in the recent state is somewhat triangular, the base of the triangle being in front and nearly vertical, while the apex is behind; the long axis is directed nearly horizontally backwards, but with an inclination downwards as well as backwards. The fossa is usually larger, and is always deeper before the articular cartilage has been removed than in the dried bone. It is also deeper in front than behind, so as to resemble a little pit, with a groove running off from it. The round ligament is *attached* only to the anterior part of the fossa, *i.e.*, the pit, and lies in the posterior part of it, *i.e.*, the groove, only when the ligament is in action, viz., in flexion, with outward rotation. In the bottom of the dimple are two or three foramina for bloodvessels.

The *neck* of the femur is inclined to the shaft at an angle of 125°. It is cylindrical near the head, and becomes flattened as it proceeds outwards. It is deeper vertically than horizontally in its outer half; it is convex in front, concave behind; is marked on the middle of its anterior surface by a slight depression for the ilio-psoas muscle, and outside this, near the root of the trochanter, there is a heaping-up of bone sometimes called the tubercle of the femur, which gives origin to the tendon of the vastus externus muscle.

The neck is overhung above and behind by the posterior and upper half of the great trochanter, and in the angle between them is the deep digital fossa. Into this fossa the tendon of the external obturator is inserted after it has passed upwards over the smooth outer third of the back of the neck, from which it is separated by a bursa. On the upper surface of the neck are numerous large foramina for the passage of nutrient vessels. At the root of the neck in front is the anterior inter-trochanteric, which is continued into the spiral, line; behind is the posterior inter-trochanteric line.

The under surface of the neck forms with the inner side of the shaft a well-marked curve or arch, which increases the strength of the bone, while it gives grace to the outline of the lower limb.

By placing the finger on the neck of the femur immediately below the fossa for the ligamentum teres, the bone balances so that the articular surfaces of the condyles are on the same level, and can together rest evenly on a flat surface.

The length of the neck varies; behind, it is about two inches and three-quarters; below, about three inches; while in front and above it is much less. As has been remarked, the articular surface of the head extends furthest on the upper and anterior aspects, and this helps to give the under and posterior sides of the neck greater length.

It is owing to the obliquity of the neck and the inclination of the acetabulum that there is but little loss of supporting power during flexion, as the head of the femur in this movement rotates within, instead of being displaced from the acetabulum, as would necessarily be the case if the axis of the head and neck had been in a line with that of the shaft, and the head had then supported the acetabulum on its summit.

It is owing to the obliquity, together with the length of the neck, that room is made between the thigh bones for the adductor muscles; and to the length—the trochanters thereby being removed from the joint—that greater leverage is given to the muscles inserted into those prominences, and that a wide range of movement is possible.

LIGAMENTS.—There are three ligaments and a circumferential or marginal fibro-cartilage in the hip-joint; these are named the capsular and the transverse ligaments, and the ligamentum teres or round ligament; the cotyloid fibro-cartilage is also generally, though improperly, spoken of as a ligament.

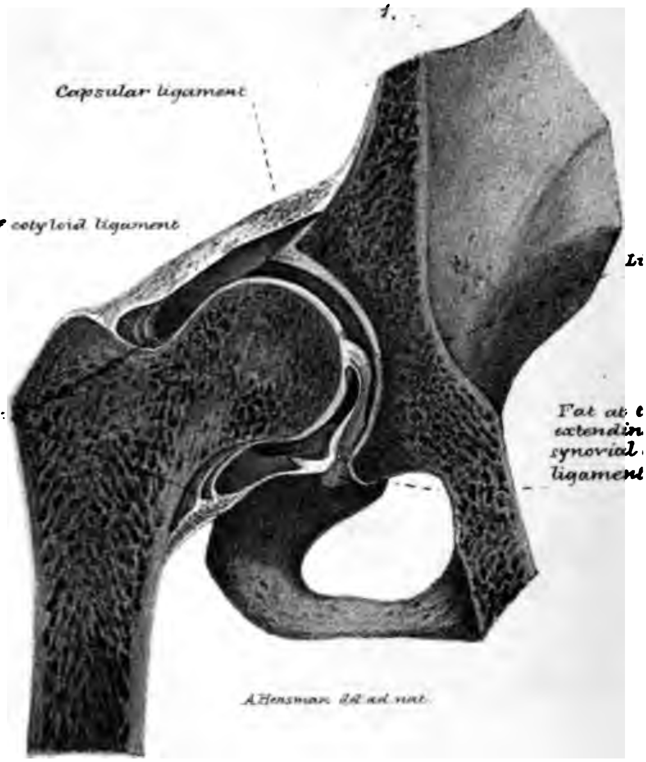
The *capsular ligament* is at once the strongest, and yet one of the weakest, ligaments in the body. Besides completely covering the articular portions of the bones, it also encloses the ligamentum teres and the cotyloid cartilage, while it partially springs from the outer surface of the transverse ligament. It is large and somewhat loose, so that in every position of the limb some portion of it is relaxed. *At the pelvis,* it is attached near to, but at a slightly varying distance from, the edge of the acetabulum. Thus superiorly it reaches as high as the base of the anterior inferior iliac spine, thence it curves backwards and becomes blended with the deep surface of the long tendon of the rectus femoris muscle. Posteriorly it is only a few lines from the acetabular rim, and is firmly fixed to the bodies of the ilium and ischium. Inferiorly it is attached to the upper lip of the groove between the acetabulum and tuberosity of the ischium, in which the posterior or lower edge of the belly of the obturator externus muscle is compressed during extension of the limb. Thus it reaches the transverse ligament, to the outer surface of which it is firmly blended, and frequently several long stout fibres are prolonged over the notch to the obturator fascia to which they are firmly attached. Anteriorly it is attached to the pubis near the notch, to the pectineal eminence, and from this backwards along the pubis to the base of the inferior iliac spine. From the superficial aspect of the capsule on the posterior part, a thin but strong stratum extends beneath the gluteus minimus and small rotators, to be attached above to the dorsum of the ilium higher than the long tendon of the rectus, and behind to the ilium and ischium, nearly as far back as the sciatic notch. As this expansion passes over the long tendon of the rectus, part of the origin of the muscle may correctly be described as being within the substance or between the layers of the capsule.

At the femur, the capsule is fixed to the anterior portion of the upper border of the great trochanter, and to the tubercle of the femur close to the insertion of the gluteus minimus and the origin of the vastus externus, with slips from each of which it is blended. Thence it runs along the upper and

PLAT

VERTICAL SECTION THROUGH HIP JOINT

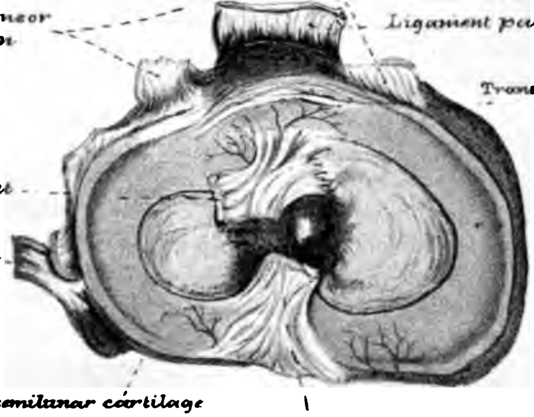
1.



HEAD OF TIBIA
WITH SEMILUNAR CARTILAGES & CRUCIAL LIGAME

LEFT SIDE

2.



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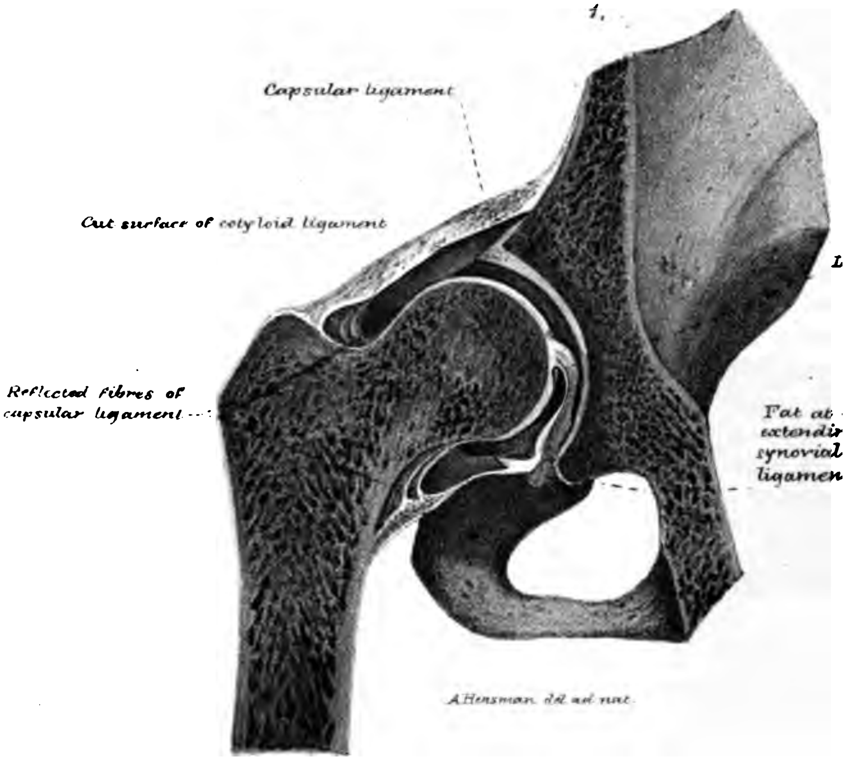
1.
Capsular ligament
Cut surface of cotyloid ligament
Reflected fibres of capsular ligament
L
Fat at
extendir
synovial
ligamen

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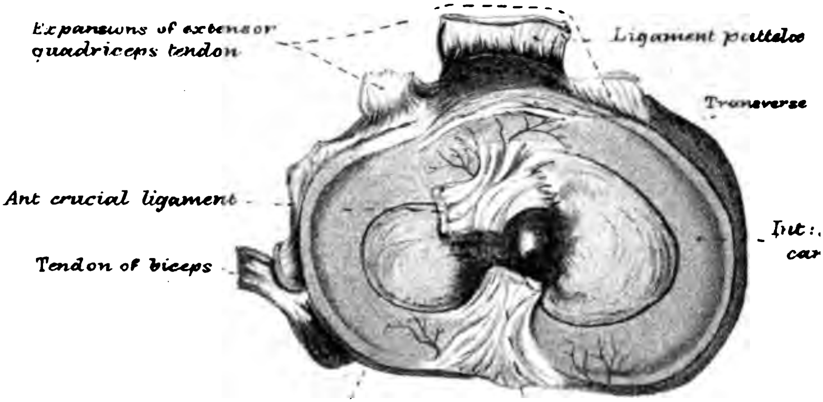
HEAD OF TIBIA WITH SEMILUNAR CARTILAGES & CRUCIAL LIGAME

LEFT SIDE

2.



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outer part of the anterior inter-trochanteric line, but it soon gets below it, and at the inner border of the femur is on the level of the lower surface of the small trochanter. It is then inclined upwards and backwards along an oblique line two-thirds of an inch in front of the small trochanter, to reach the back of the neck; here it is attached above the posterior inter-trochanteric line at a distance varying from half an inch, at the lower and upper ends, to over two-thirds of an inch opposite the middle of that line.

Several strong fibres containing fatty tissue between them are fixed at the inner side of the digital fossa, beneath the small external rotator tendons; they are continuous in front with the fibres attached to the anterior superior angle of the trochanter.

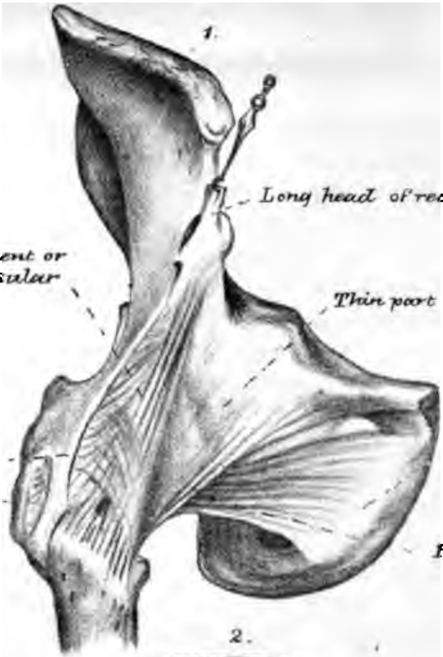
After laying open the capsule it is seen that some of the deeper fibres of this ligament are reflected upwards along the neck, so as to be attached to the femur much nearer its head. These reflected fibres occur at three places, one corresponding in position to the middle of the ilio-femoral ligament, another to the pectineo-femoral, and the third on the upper and back part of the neck. A thin fold of synovial membrane stretches between the reflected and the unreflected fibres of the capsule. There are also to be seen encircling more or less of the capsule, but more especially the anterior and upper parts, many obliquely transverse fibres. These are placed superficial to the fibres passing from ilium to femur; several of them blend with the inner portion of the ilio-femoral ligament near the femur, and above are lost beneath the expansion from the gluteus and vastus externus to the capsule.

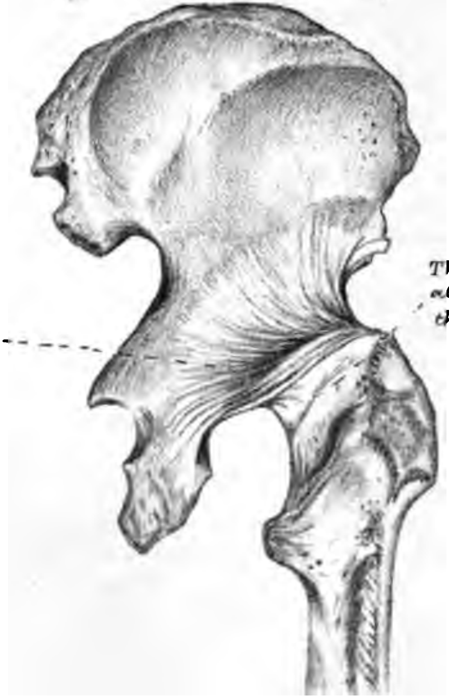
In thickness and strength the capsule varies extremely in different parts; thus, if two lines be drawn, one from the anterior inferior iliac spine to the inner border of the femur near the lesser trochanter, the other from the anterior part of the groove for the external obturator (*i.e.*, the upper part of the tuberosity of the ischium) to the digital fossa, all the ligament outside and above those lines is very thick and strong; whereas all to the inner side and below, except along the narrow pectineo-femoral band, is very thin and weak, so that the head of the bone can be seen through it. It is thickest in the course of the ilio-femoral ligament, at the outer part of which it is over a quarter of an inch in thickness; it becomes thinner towards the lower border of the ischio-femoral band, although here it is seldom less than one-eighth of an inch thick near the acetabulum, where the fibres are extremely well-marked.

There are three sets of auxiliary fibres, which have been already alluded to under separate names—viz., ilio-femoral, ischio-femoral, and pectineo-femoral.

The ilio-femoral band is the longest and widest, as well as the thickest of the three. Above it is connected in a curved line (with the convexity upwards), two-thirds of an inch in length, to the ilium immediately below and behind the anterior inferior spine; thence it extends obliquely downwards and outwards to the front of the trochanter major, and the anterior trochanteric and spiral lines as far as the inner border of the shaft. Its fibres have not all the same degree of obliquity, for those which are highest on the ilium have also the highest femoral attachment, and *vice versâ;* so that the uppermost fibres are shorter and more nearly transverse than the rest; the central fibres take a straight course, and are fixed to the femur, where the spiral joins with the inter-trochanteric line. This varying obliquity of the fibres, together with some accumulation of the fibres both along the inner and outer borders of the band near the femur, possibly explains how it has come to be described as the Y-shaped ligament. It has been said to resemble an inverted Y, one arm of which is supposed to be attached near the trochanter major, and the other to the spiral line near the inner border of the femur, with but little, if any, ligamentous tissue between them. This, however, is not correct, for although the appearance may be produced by dissection (and especially if the strong dense fibres between the capsule and gluteus minimus, and between the long tendon of the rectus and the tendon of origin of the vastus externus, be not removed), it does not naturally exist. About the centre of the band, near its attachment to the trochanteric line, is an aperture leading into the joint. It is very constant, and transmits the transverse branch of the external circumflex artery through the ilio-femoral ligament into the joint. This portion of the capsule limits extension, and by pre-

FRONT VIEW OF CAPSULAR LIGAMENT OF HIP JOINT


1.
Long head of rectus cut & h
Ilio femoral ligament or strong part of capsular ligament
Thin part of capsular l
Obturator muscle
Tendonous band between vastus ext: & rectus muscles, strengthing capsule
Pectineo-femo


2.
Thin part of attached to the neck of th
Zonular fibres of back of capsule.
The Ischio-femoral band.

. BACK VIEW OF CAPSULE OF HIP JOINT

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venting the natural tendency of the trunk to roll backwards on the thigh bones in the erect posture, it does away with the necessity of muscular power for this purpose. It is made tense in every position of extension except when abduction is combined with extension, and then the outer fibres are relaxed. Abduction might be described as flexion outwards, so that the points of attachment of the outer fibres are approximated. When adduction is combined with complete extension the points of attachment separate, and the whole ligament (but especially the inner portion of it) is put upon the stretch. The outer fibres are tightened in outward rotation even during flexion. In extension with outward rotation the whole ilio-femoral band is tight, but as flexion is increased the outer fibres become more and more tense as the inner ones are relaxed. In rotation inwards the inner fibres of the ligament receive most of the strain.

The ischio-femoral band is formed by very strong fibres attached all along the upper border of the groove for the external obturator, and to the ischial margin of the acetabulum above the groove. The highest of these incline a little upwards as they pass outwards to be fixed to the trochanter in front of the insertion of the pyriformis tendon; the other fibres, as they pass outwards, curve more and more upwards, and are fixed to the upper and back part of the neck internal to the digital fossa, where they are blended with the tendons of insertion of the external rotators. When the femur is flexed these fibres pass in almost straight lines to their femoral attachment, and are spread out uniformly over the head of the bone; but in extension of the thigh they wind upwards over the back of the head and neck of the femur in a zonular manner, and form quite a folded band along the lower border of the ligament.

This band does not limit simple flexion, nor is it made tight until adduction or rotation inwards is combined with flexion. In flexion with rotation outwards, or with abduction, it is quite relaxed, as it is also in extension.

Between the ilio- and the ischio-femoral bands the capsule is stout and strong, and with it here, near the acetabulum, is incorporated the long tendon of the rectus; while at the femoral end the longitudinal fibres composing it are concentrated to a narrow insertion into the ridge on the front border of the trochanter close to the gluteus minimus. It is this portion of the capsule which is greatly strengthened by a strong fasciculus of fibres passing from the under surface of the gluteus minimus to the capsule half-way between the iliac and femoral attachments; while further forwards, and near to the outer edge of the ilio-femoral ligament, a tendinous band, closely blended with the surface of the capsule, stretches between the upper extremity of the tendon of origin of the vastus externus and the long tendon of the rectus. By this band traction on either of these tendons moves the other in the dissected joint, so that it is possible there is some direct association in their action. This part of the capsule assists the ilio-femoral ligament in limiting extension, but it is made tighter in adduction, especially in adduction combined with slight flexion, *e.g.*, the stand-at-ease position of the limb upon which the weight of the body is not resting.

The pectineo-femoral band is a distinct but narrow set of fibres, individually less marked than those of either the ilio-femoral or ischio-femoral ligaments. They are fixed above to the anterior border of the pectineal eminence reaching down as far as the pubic end of the cotyloid notch; to the neck of the femur they are attached above and behind the ilio-femoral ligament, with the lowermost fibres of which they blend. It is put upon the stretch in abduction, whether combined with flexion or extension; it is very tight in abduction combined with rotation outwards and flexion, and abduction with slight simple flexion. In both these latter positions the head of the bone is in great part out of the acetabulum, and supported by the fibres of this band; whilst both the ischio- and ilio-femoral bands are relaxed.

The fibres of all these auxiliary bands are superficial to, but inseparably blended with, the rest of the capsular ligament; in fact, although called by distinct names, they are in no way distinct ligaments, but merely very greatly thickened portions of the capsule.* The ilio-femoral fibres and the ischio-femoral, near the ischium, are very distinguishable by their greater coarseness. The ilio-femoral and pectineo-femoral bands, and the pubic rim of the acetabulum, enclose a triangular space where the capsule is thinnest. This part is never tightly stretched in any position of the joint; over it the ilio-psoas muscle passes, only separated from it by a bursa, which sometimes communicates with the synovial sac.

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* In one instance, described in the eighth volume of "Journal of Anatomy and Physiology" (p. 134), an abnormal ligament was observed stretching from the ischium to the trochanter, and quite distinct from the capsule in its posterior half.

The capsule, opposite the lower and back part of the neck of the femur, especially near its attachment to the back of the femoral neck, and again opposite the cotyloid notch, is very thin. It is, however, thickened near the transverse ligament by some curved and decussating fibres, which arise from each extremity of the ligament; the hinder ones pass forwards and blend with the pectineo-femoral band in the middle of its course, those which arise in front are lost on the under and back part of the capsule. Some extra fibres from the border of the external obturator groove help to strengthen the under part of the capsule, and are lost upon it. In nearly every position of the joint it is relaxed, but there is one, viz., extreme flexion combined with abduction, in which it has to resist the head of the bone when all the rest of the capsule, except the pectineo-femoral ligament, is quite relaxed. Such a position is assumed when the thigh is thrown sideways over the arm of an easy-chair, or when sitting in a hip-bath with the thighs apart, and the knee bent over the edge, or in stooping low with the legs wide apart.

The capsular ligament is supported externally by muscles and tendons on every side, and by several of them great additional strength is given to the joint. Some of them, from being closely connected with the ligament, serve to raise it during the movement of the joint, and thus prevent it from being pinched against the edge of the acetabulum.

In front is the ilio-psoas muscle, the sheath of which is adherent to the capsule, while the iliacus in part arises from it. Above are the rectus femoris, the slip from the vastus externus to the long head of the rectus, and the gluteus minimus with its strong fibrous connexion with the capsule. Above and behind are the pyriformis (a slip from which joins the tendon of the small gluteal), and behind the internal obturator and gemelli. The obturator internus is by far the strongest of all the small rotators, and acts much like a ligament, owing to the extension backwards of many of the ultimate fibres of its several tendons well-nigh to the bony origin of the muscle; the four or five closely formed tendons which pass over the ischial groove result from the blending of eight or nine strong bands, which are seen on raising the muscle from its origin; these bands radiate along the borders and the body of the muscle, and extend from within a short distance of its extreme limits, while they again are composed of individual slender fibres, which pass from origin to insertion of the muscle. Its power of resistance too is increased by the play of the tendons over the trochlear groove of the ischium, whereby strain on the muscles is diminished.

Below, and behind, the external obturator muscle passes over the capsule; some few of its upper fibres are inserted into the under part of the ligament, and a dense band of fibro-cellular tissue, extending from the groove to the digital fossa, connects its sheath with the capsule along the posterior border of the muscle. As the tendon of the muscle approaches the digital fossa, it turns on its own axis and rests on the neck of the femur along the line of attachment of, and beyond the capsule.

The ligamentum teres, or round ligament, is an inter-articular flat band, which extends from the acetabular notch to the dimple in the head of the femur. At the acetabulum it has two bony attachments, one on each side of the notch, while intermediate fibres spring from the under surface of the transverse ligament; indeed, some lowermost fibres of the transverse ligament consist of these intermediate fibres of the round ligament. It is usually about one and a half to one inch and three-quarters long. *To the acetabulum*, on the pubic side of the notch, it is fixed to the acetabular surface, immediately below the articular cartilage. On the ischial side it is also fixed close to the notch, immediately below the articular facet, but several of the fibres arise outside the cavity, below and in connexion with the origin of the transverse ligament, where it is also continuous with the capsular ligament and periosteum of the ischium. The posterior or ischial portion is much stronger than the anterior or pubic, but it is not strictly correct to say that the origin is bifid, as between the posterior and anterior bands there are the fibres connected with the under edge of the transverse ligament. *To the femur* the ligament is attached at the anterior part (*i.e.*, the pit) of the dimple in the head, as well as to the cartilage which forms the margin of this part of the dimple. Its axis of insertion corresponds to the base of the triangular-shaped dimple; the ischial fibres pass chiefly into the upper angle, the pubic fasciculus into the anterior and lower angle.

In connexion with the ligamentum teres the fatty tissue at the bottom of the rough recess in the acetabulum requires a word of notice. It forms quite a thick quadrangular pad or cushion, which occupies all the non-articular portion of the cavity, and projects outwards, beneath the transverse ligament, through the acetabular notch. Into it pass the articular nerves and arteries, which, as they enter the cavity to run along the round ligament to the head of the femur, lie between the bony origins of the ligamentum teres, and beneath its connexion with the transverse ligament. The synovial membrane which covers the fatty cushion is of unusual thickness; from the cushion, as well as from the lower edge of the transverse ligament, the synovial membrane is reflected along the round ligament to the head of the femur. The part of the membrane reflected from the cushion does not cleave closely to the round ligament, but forms a triangular fold, the apex of which is at the dimple in the head of the femur; one side is continuous with the round ligament, and the other, free, looks towards the back of the acetabulum; while the flat surfaces (in the erect posture) face towards and from the lower part of the femoral head. The ligamentum teres presents the appearance of two triangular planes at right angles to each other, one formed by the broad fibrous ligament, and the other by the reflected synovial membrane as described above. The ligamentum teres is shut out from the synovial cavity of the joint by the reflected membrane, as the lungs are by the pleura, and the abdominal viscera by the peritoneum.

The use of the ligamentum teres is to check rotation outwards during flexion, and adduction during flexion. As a ligament can only be in use when it is tight, and as there have been various and very different opinions published as to the positions which the joint is in when the round ligament is tight, I shall give the results of different modes of examination.

When examined after division of the entire circumference of the capsule, the round ligament is on stretch during extension, and adduction in the nearly extended position. During simple extension, the ischial band is alone tense; during extension with adduction, the rest becomes tense also.

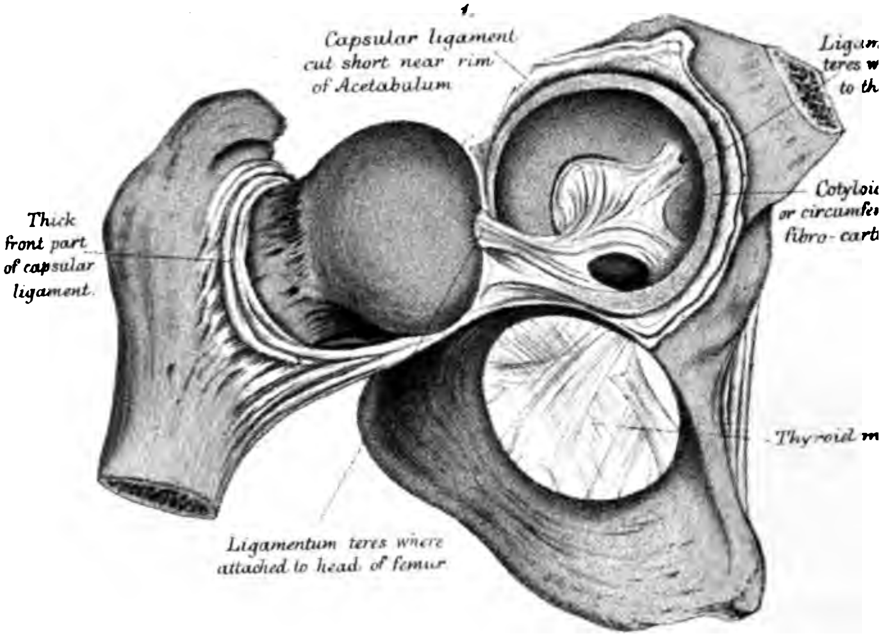
After trephining the acetabulum, removing the fat and synovial membrane corresponding to the excised bone, and dividing the fibres of the ilio-femoral ligament through part of its thickness, then adduction in the nearly extended position brings the ligament tight, though perhaps not so tight as rotation outwards with flexion. But if the ilio-femoral ligament be left untouched, so that it offers its full resistance in extension and adduction, there is no tension on the ligamentum teres in the extended or nearly extended positions; but the ligament is still very tight during flexion combined with outward rotation. In this position the ligament is quite flat, and rests in the posterior portion of the dimple (*i.e.*, the groove) of the head of the femur. In flexion with adduction it is also tight; the fibres are almost flat, but twisted a little on themselves near the dimple of the femur. During adduction, as the limb passes from flexion into extension, the round ligament gets less and less tight until it becomes quite lax. After flexion with adduction, it is as tight in flexion with rotation inwards as in any other position. It is at its loosest in abduction with flexion, in which position the two ends of the ligament are close together, and opposite to one another. It is very loose in abduction with extension. It is also loose in abduction combined with flexion and outward rotation.

The tension of the ligament was tested by threading a piece of whipcord round it and pulling on the cord in the various positions. In this mode of examination, the results are very unmistakable—viz., the ligament is tightest in flexion combined with adduction and rotation outwards, and almost as tight in flexion with external rotation alone; and in adduction combined with flexion. Its most lax state is in abduction.

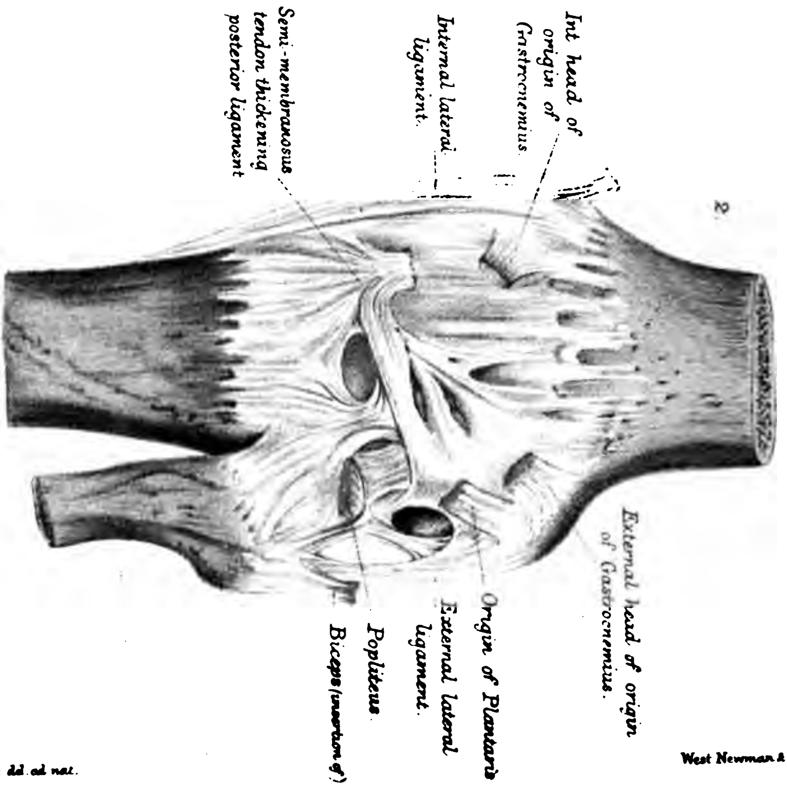
As this method of examination requires the removal from the floor of the cavity of a piece of the synovial membrane near where it is reflected along the round ligament, and as this reflected synovial membrane, together with the fibrous ligament itself, forms a broad triangular structure, it was deemed well

HIP - JOINT AFTER DIVIDING CAPSULAR LIGAMENT AND DISARTICULATING THE FEMUR.

1.


Capsular ligament cut short near rim of Acetabulum
Ligam teres w to th
Thick front part of capsular ligament.
Cotyloid or circumfe fibro-cart
Thyroid m
Ligamentum teres where attached to head of femur

2


Int head of origin of Gastrocnemius
Internal lateral ligament.
Semi-membranosus tendon thickening posterior ligament
External head of origin of Gastrocnemius.
Origin of Plantaris
External lateral ligament.
Popliteus
Biceps (insertion of)

F. Steele del. ad nat.

West Newman &

embraces a little beyond its greatest circumference. It somewhat contracts the aperture of the acetabulum, and retains the head of the femur within its grasp after the capsule and all muscles have been completely divided. It is firmly fixed to the bony rim, as well as to the articular cartilage on the inner, and the periosteum on the outer side of it, while at the notch it is inseparably blended with the transverse ligament, if indeed it can be said to exist at all as a distinct structure. It is covered on both aspects by the synovial membrane, which is reflected over its free edge from the capsule to the articular cartilage of the acetabulum.

The *articular cartilage* lines a large part of the acetabulum, and covers the smooth portion of the head of the femur. In the acetabulum the width and thickness of the cartilage are great in those parts which have to bear most pressure, and greatest on the ilium behind a vertical line from the anterior inferior spinous process. To the head of the femur the cartilage gives much the appearance of a white billiard-ball; to the dimple for the round ligament it gives the raised margin and triangular shape seen in the recent state, for as soon as the cartilage is removed the appearance of the dimple is much altered. Into it at the dimple (especially at the upper margin) the round ligament is inserted, and a large scale is often torn away with the ligament from off the femur in dislocation of the thigh. It is much thicker over the upper than the lower part, and is thicker near the dimple than towards the circumference. At its thickest part, just above the dimple, it is about one-twelfth of an inch deep, while at the under part of the head it is so thin that the bone can be seen through it. The extent of the cartilage corresponds with the smooth part of the head of the dried bone, and its limit with the sinuous outline of the head.

The SYNOVIAL MEMBRANE lines the capsule, and passes over the border of the acetabulum to reach the fatty cushion and the round ligament. By the latter it is conducted, in the manner already described, to the head and neck of the femur, and thus to the femoral attachment of the capsule.

ARTERIES.—Blood is supplied to the hip-joint from the deep femoral and the internal iliac arteries.

(1) *From the deep femoral,* the transverse branch of the internal circumflex as it winds above the small trochanter

gives off, when opposite the joint, an articular branch which enters at the cotyloid notch, supplies the fatty tissue, synovial membrane, and round ligament, and, like the following, sometimes reaches the head of the femur.

(2) The transverse branch of the external circumflex, as it passes outwards beneath the vastus externus, gives a branch of considerable size to the joint. It enters through a well-marked and constant aperture in the ilio-femoral band a little above the middle of its femoral attachment.

A second branch, from the same source, sometimes enters the joint through the ligament lower down.

(3) *From the internal iliac,* blood is derived through the obturator, gluteal, and sciatic branches. The external, lower, and posterior branch of the obturator gives an articular twig, which enters beneath the transverse ligament, ramifies in the fatty cushion of the acetabulum, and runs along the round ligament to the head of the femur.

(4) The inferior division of the deep portion of the gluteal sends small branches to the hip, which pierce the gluteus minimus and penetrate the capsule.

(5) The sciatic artery gives off directly some branches to the back of the capsule of the joint; and the branch from it to the quadratus femoris, after passing beneath the gemelli and internal obturator, sends twigs to the hip-joint before it terminates in the muscle.

NERVES are derived from the lumbar and sacral plexuses. From the lumbar plexus (1) the *anterior crural* furnishes one or more branches to the front part of the capsule, as the nerve is passing over the joint, and just after it has escaped from beneath Poupart's ligament. (2) The anterior portion of the *obturator* sends articular branches to the hip-joint when near the thyroid membrane, one of which enters at the acetabular notch, and reaches the ligamentum teres, another supplies the anterior, while a third goes to the lower part of the capsule. (3) The *accessory obturator,* when present, gives off, behind the pectineus muscle, an articular branch, which sometimes enters the hip-joint with the branch of the obturator artery, and at others perforates the capsule.

From the sacral plexus (1) the nerve to the quadratus femoris furnishes a small branch to the back of the joint, while it is lying between the external rotators and the capsule. (2) Several branches, derived either from the upper part of the great sciatic nerve, or from the lower part of the sacral plexus itself, or from both sources, enter the joint by perforating the back of the capsule.

Bursæ are found on the front, outer side, and back of the joint. On the front and outer side there are five, viz.—

1. A large bursa beneath the psoas and iliacus, between them and the thin portion of the capsular ligament. It often communicates with the synovial cavity of the joint.

2. A small bursa between the gluteus medius and the upper and front part of the trochanter major. It extends some way between the tendon of this muscle and that of the pyriformis, which is covered by the gluteus. Sometimes there are two bursæ instead of one; one between the tendon and the bone, another between the tendon and the pyriformis.

3. Between the tendon of gluteus minimus and the front of the trochanter. This bursa sometimes extends between the insertion of the small gluteus and the origin of the vastus externus tendon.

4. A large bursa is situated in front of the gluteus maximus, and between it and the vastus externus; over it rides the strong fascia of the buttock as it passes downwards to the thigh towards the insertion of the gluteus maximus. It is below the following:

5. A large multilocular bursa extends across the external surface of the base of the great trochanter, and some way upon the shaft below, over which the tendon of the gluteus maximus and the dense fascia play.

On the back of the joint there are four bursæ, viz.—

6. The external obturator muscle plays over a bursa which is situated between it and the back of the neck of the femur.

7. A large bursa exists between the quadratus femoris and the posterior surface of the small trochanter.

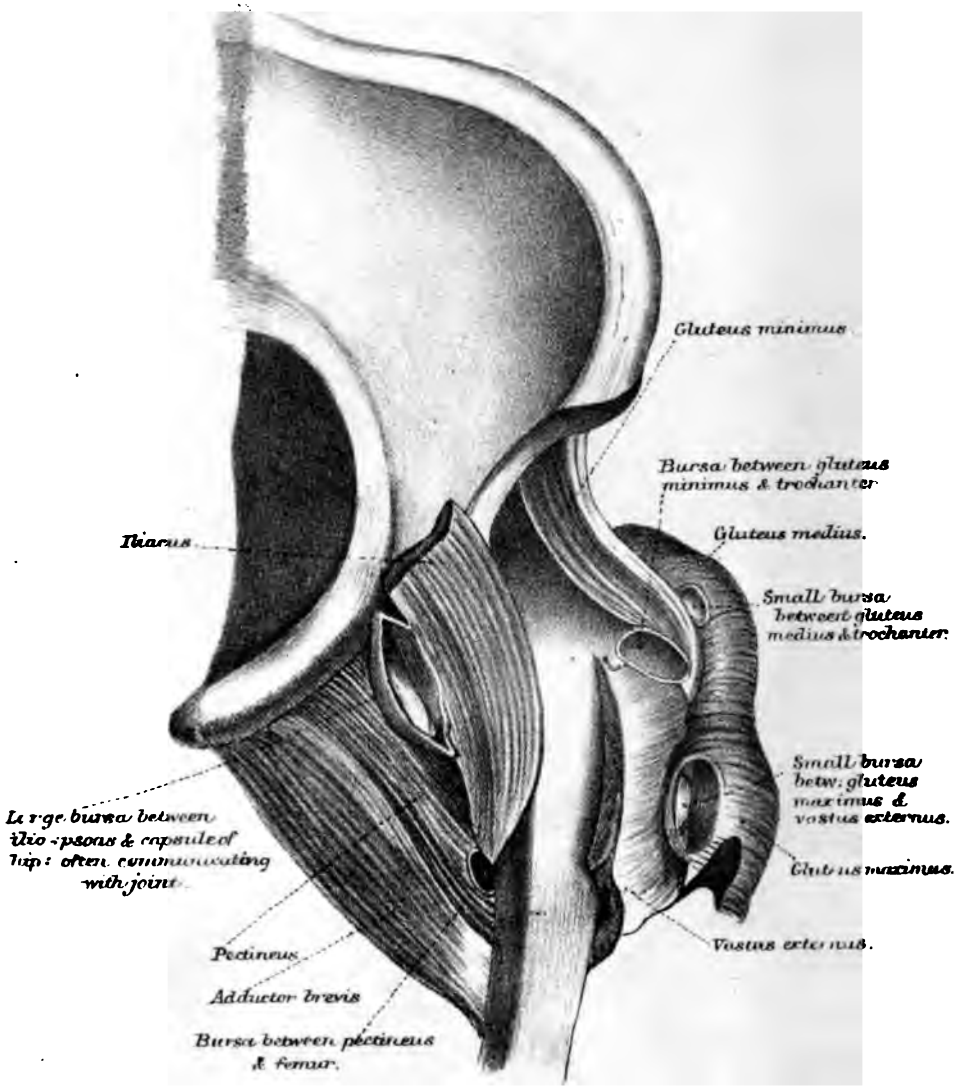
8. An elongated bursa often exists between the back of the capsule and the gemelli and internal obturator muscles. It is often in communication with the bursa which lies between the latter muscle and the trochlear groove of the ischium.

9. Bursal interspaces, containing a light currant-jelly-coloured fluid, occur between the quadratus femoris and the obturator externus and back part of the capsule.

Muscles.—Numerous muscles act upon the hip-joint. Some

PLATE XXX.

BURSÆ IN CONNECTION WITH THE FRONT OF THE HIP JOINT.

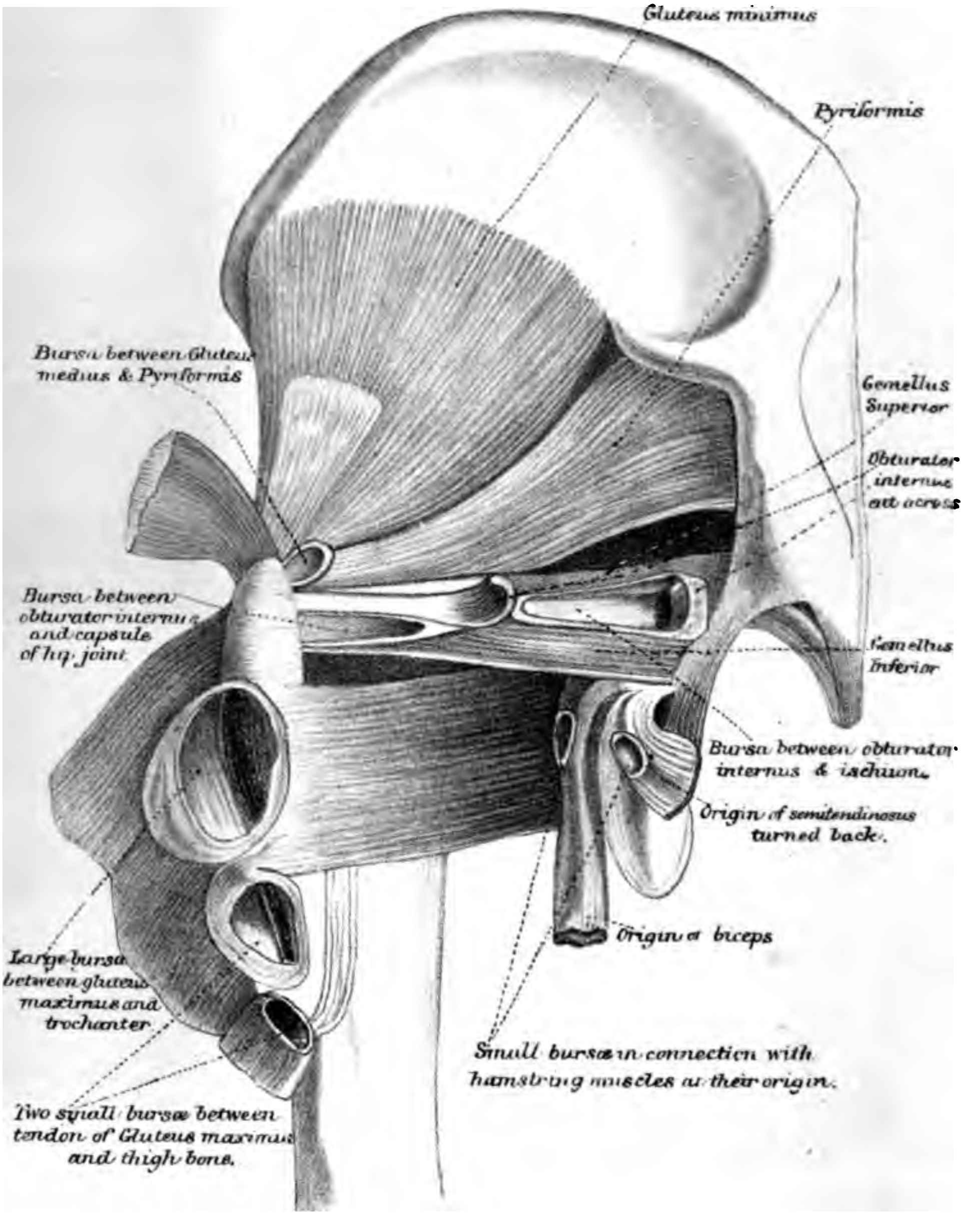

Gluteus minimus
Bursa between gluteus minimus & trochanter
Gluteus medius.
Small bursa between gluteus medius & trochanter.
Iliacus
Small bursa betw: gluteus maximus & vastus externus.
Gluteus maximus.
Large bursa between ilio-psoas & capsule of hip: often communicating with joint.
Vastus externus.
Pectineus
Adductor brevis
Bursa between pectineus & femur.

Hensman del. after Munro.

West, Newman & Co. Lith.

PLATE XXXI.

BURSÆ ON THE BACK OF THE HIP


Gluteus minimus
Pyriformis
Bursa between Gluteus medius & Pyriformis
Gemellus Superior
Obturator internus cut across
Bursa between obturator internus and capsule of hip joint
Gemellus Inferior
Bursa between obturator internus & ischium.
Origin of semitendinosus turned back.
Origin of biceps
Large bursa between gluteus maximus and trochanter
Small bursæ in connection with hamstring muscles at their origin.
Two small bursæ between tendon of Gluteus maximus and thigh bone.

man del. after Monro.

West, Newman & Co. Lith.

of them confine their action to it, others pass over and act upon the knee-joint also. Those which influence both joints are the sartorius and gracilis, the rectus femoris, the three hamstrings, and the fascial prolongations of the tensor vaginæ femoris.

Some of the muscles which act on the hip arise beyond the hip-bone, viz., the psoas, the pyriformis, and part of the gluteus maximus. All the rest arise from the os innominatum, and with the exception of those which have been mentioned as passing beyond the knee, are inserted into the femur, *i.e.*, extend only between the two bones of the articulation.

They must be grouped according to the various movements of the joint, as flexors, extensors, abductors, adductors, rotators outwards and inwards. Circumduction being a movement in which flexion, extension, abduction, and adduction follow each other in quick succession, the muscles which produce it consist of those which effect the various component movements. Several of the muscles fall under more than one group.

Flexors.—The psoas and iliacus, often spoken of conjointly as the ilio-psoas muscle, are the strongest and most direct flexor; the pectineus, which acts also as an adductor, and the sartorius and rectus, when their action on the leg is completed or prevented.

The vastus externus, by its undescribed band to the rectus tendon, probably assists slightly in flexing the thigh on the trunk, and the trunk on the thigh. The obturator externus occasionally acts as a flexor, as in crossing the thighs; this action is very decided.

Extensors.—The hamstrings, when their tendency to bend the leg is fulfilled or prevented, extend the hip, but their action on the two joints often, indeed generally, is produced simultaneously, the leg being bent at the knee as the thigh is extended at the hip, as in the first act of rising from a seat. The gluteus maximus, gluteus medius, and gluteus minimus are all extensors of the hip, and are so placed as to be able to take up action one after the other, according to the degree of flexion to be overcome. This can be proved by feeling the muscles with the fingers in rising from the sitting posture (by which the thighs are straightened under the trunk), or from the stooping posture (by which the trunk is extended on the thighs). In the early part of either of these movements, the small gluteal are felt to be firmly contracted, while as the erect posture is nearer and nearer attained, the gluteus maximus contracts more and more, and the smaller muscles become flaccid. Their large development, and the coarse fibres of the great gluteal, are required in the human subject to bring back the body into the erect position, but not to keep it there; this latter office is done by the line of gravity, by the position of the hip-joints and pelvis with regard to that line, and by the powerful ilio-femoral ligament. The obturator internus assists extension from the position of flexion and rotation outwards, as in uncrossing and extending the thigh.

Adductors.—These consist of the group of muscles of the name, on the inner side of the thigh, all of which pass directly between the innominate bone and the femur. In addition, there are on this same aspect of the limb the pectineus, which is also a flexor, and the gracilis, which besides being an adductor, extends beyond the knee and rotates the leg inwards. Three muscles pass behind the joint, which act occasionally as adductors, viz., the gluteus maximus, which does so when the limb is extended, and the external obturator, which adducts the flexed thigh, as in crossing one limb in front of the other. The quadratus femoris, when extreme rotation outwards is either prevented or completed, acts as an adductor.

Abductors.—The gluteus medius and gluteus minimus are powerful abductors, and are the muscles chiefly concerned in supporting the pelvis on one thigh; in so doing they act as abductors, for when standing on one limb the opposite side of the pelvis is raised, and thus a position which corresponds with abduction of the thigh is the result.

The upper fibres of the gluteus maximus and the tensor vaginæ femoris are important aids for the same purpose. The tensor fasciæ assists the action of the gluteus maximus by making tense the fascia, and has some influence in extending the knee by the direct prolongation of the fascia lata to the external oblique line on the tibia.

The sartorius abducts the thigh at the same time that it flexes both the hip and the knee.

Inward Rotators.—The anterior portion of the gluteus medius and gluteus minimus, and the tensor vaginæ femoris, all act as inward rotators.

Outward Rotators.—These muscles are numerous, and occur on the sides of the joint. In front is the ilio-psoas, a powerful outward rotator, as well as the chief flexor of the hip. On the inner side are the pectineus and the three adductors, the former of which being inserted behind and below the small trochanter, and the rest into the linea aspera, are all advantageously situated for rolling the thigh outwards. On the under aspect the obturator externus passes from its origin on the inner side of the acetabulum to its insertion into the digital fossa. On the back of the joint from below upwards are the quadratus femoris, the gemelli and obturator internus, the pyriformis, and the posterior portion of the gluteus minimus and medius; while covering all these is the gluteus maximus, also a considerable outward rotator. The biceps is an outward rotator when the knee is extended.

It is important to observe that muscles concerned in producing each of the angular movements of the thigh act as outward rotators, viz., the chief flexor, all the adductors, the two chief abductors, and the great extensor. The necessity of these numerous and powerful outward rotators results from the relation of the pelvis to the fixed limb in walking, running, &c., and the inclination outwards of the advancing limb. This backward rotation of the pelvis on the side of the firm thigh, corresponds to an inward rotation of the same thigh; so that when this limb, in its turn, comes to be advanced, not only has it to be rotated outwards, so that the toes may escape past the other foot, but a considerable amount of inward rotation has also to be first overcome.

A result of the same muscles being rotators outwards, as well as flexor, extensors, adductors, or abductors, is that each of these other movements can be carried much further (except abduction) when the thigh is rotated outwards; this is markedly the case with flexion and adduction, and follows naturally from the fact that if one of the actions is rendered unnecessary, the whole force of the muscle is devoted to the other action, *i.e.*, if rotation outwards has been completed by other muscles, the whole force of the contracting ilio-psoas or adductors is directed to bending or adducting respectively.

Abduction can be carried somewhat further during rotation inwards, because the gluteus medius and minimus, which are the chief abductors, are also, by their anterior fibres, rotators inwards; so likewise is the tensor fasciæ; and unless rotation inwards has been completed or is prevented, the power of these muscles must of necessity be partly diverted from producing abduction.

It is common to find considerable blending of the tendons of the pyriformis and the obturator internus at their insertions, and a strong slip generally connects the pyriformis with the gluteus minimus. There is, doubtless, purpose in this arrangement. As has been said, the gluteus minimus by its anterior and middle fibres rotates the thigh inwards, by its posterior fibres outwards; as soon as these latter fibres have contracted the pyriformis takes up the outward rotation by the slip, which it sends to join the gluteus, then by its own direct fibres of insertion, then by the fibres blended with the internal obturator, and thus the movement of outward rotation is continued by the obturator and gemelli, and finally by the quadratus. There is thus a connexion between and a graduation in the direction of the successive fibres whereby rotation outwards is commenced, continued, and completed.

MOVEMENTS.—The hip, like the shoulder, is a ball-and-socket joint, with a much more complete socket, but a corresponding limitation of movements. Each variety of the ball-and-socket joint movements can be effected at the hip, viz., flexion, extension, abduction, adduction, rotation, and circumduction. Any two or more of these movements not being antagonistic can be combined, *i.e.*, flexion or extension associated with abduction or adduction can accompany rotation outwards or inwards. When abduction, adduction, extension, and flexion are spoken of, reference is generally made to the movements of the thigh on the pelvis, but it must be borne in mind that the pelvis moves upon the thigh, and a clear idea should be obtained of these corresponding movements of the pelvis. *During extension*, abduction of the thigh corresponds with a tilting of the opposite side of the pelvis upwards; adduction, with a lowering of the opposite side. Rotation inwards of the thigh corresponds with a swerving forwards of the opposite anterior superior iliac spine; rotation outwards with a swerving backwards of the opposite side of the pelvis. *During flexion*, abduction of the thigh corresponds with a backward, and adduction with a forward movement of the opposite side of the pelvis; rotation inwards of the thigh corresponds with elevation, rotation outwards with depression of the opposite side of the pelvis.

Flexion of the thigh corresponds to an inclination forwards, extension of the thigh to an inclination backwards of the trunk. The differences between the movements of the trunk in the flexed and extended position respectively, which correspond to abduction, adduction and rotation of the thigh, though not at first thought clear, are evident with the articulated thigh before one, and become obvious by remembering that whether during extension or flexion in abduction and adduction, the top of the trochanter approaches to and departs from respectively the hollow of the dorsum of the ilium, whereas in rotation inwards and outwards the anterior superior corner of the trochanter approaches to and departs from respectively the crease in the groin.

It results from the obliquity of the neck of the femur, that the movements of the head in the acetabulum are always more or less of a rotatory character. This is more especially the case during flexion and extension, and two results follow from it. First, the bearing surfaces of the femur and acetabulum preserve their apposition to each other, so that the amount of articular surface of the head in the acetabulum does not sensibly diminish *pari passu*, with the transit of the joint from the extended to the flexed position, as would be the case necessarily if the movement of the head, like that of the thigh, was simply angular instead of rotatory and angular. Secondly, as rotation of the head can continue until the ligaments are tight without being checked at all by the contact of the neck of the thigh-bone against the rim of the acetabulum (which is not the case with angular movements of ordinary ball-and-socket joints), flexion of the thigh, so far as the joint itself is concerned, is practically unlimited.

Diagram VI.

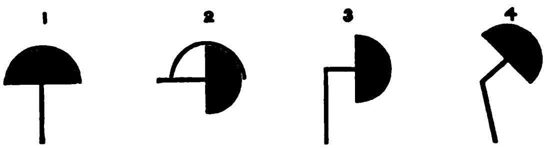


Figure 1 shows that rotation of the spherical head of a bone within its socket can take place without any loss of contact of apposed osseous surfaces. Figure 2 shows how the angular motion throws part of the head out of the socket, and leaves part of the socket unsupported; and how, in flexion to a right angle, the amount of surfaces in contact is reduced to one-half. Figure 3 shows how this result of flexion would be obviated if the head were placed at right angles to the shaft; and figure 4 shows how this disadvantage is diminished by the head and neck being placed obliquely upon the shaft of the femur.

Flexion is the most important, most frequent, and most extensive movement at the hip-joint. In the dissected limb, before the ligaments are disturbed, it can be carried to 160°, and then is checked by the lower fibres of the ischio-femoral ligament. In the living subject, simple flexion can be continued until checked by the contact of the soft parts at the groin, if the knee be bent; if the knee be straight, flexion at the hip is checked in most persons by the hamstring muscles at nearly a right angle; the checking influence of the hamstrings becomes very evident on attempting to touch the ground with the fingers without bending the knees, when the chief strain of this flexion of the trunk on the thigh is felt at the borders of the popliteal space. It is probable that Weber refers to flexion at the hip *with the knee straight*, when he says it is usually in the living person limited to 86°. The extent to which flexion can in some cases be carried, is seen when an acrobat throws one foot behind his neck while standing on the other leg; and in any person of ordinary activity, if the spinal column be fixed and the pelvis steadied, flexion, in the abducted and outwardly rotated position, can be carried through between 145° and 150° when the knee is bent, and a little pressure is exerted by the hand upon it.* In fact, under these conditions, I have proved that the degree of flexion at the hip-joint of a muscular and somewhat robust man, of five feet eleven inches in height, is as great as that at the hip-joint of a healthy lad of twelve years, when under the influence of chloroform, whose leg on the same side had been removed just above the knee.

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* The angle of flexion I accurately ascertained in one case to be 150°, by means of a nine-inch circular station measuring instrument, placed at my disposal by the surgical instrument maker, Mr. Hawksley.

Extension is limited by the ilio-femoral ligament. Abduction and outward rotation can be performed freely in every position of flexion and extension. Abduction is limited by the pectineo-femoral ligament; outward rotation, by the ilio-femoral ligament; by the inner part of it, *especially*, during extension, but by the outer part of it, as well as by the ligamentum teres, during flexion.

Adduction and inward rotation are very limited in the extended thigh; the former, because of the contact with the opposite limb; the latter, because all the muscles of inward rotation, the tensor vaginæ femoris excepted, are also extensors, whereas most of the other extensors are also outward rotators; so that each set requires to be relaxed by flexion before inward rotation can be perfected.

In the nearly extended position, adduction is more free, and is limited by the outer fibres of the ilio-femoral ligament, and by the thick superior part of the capsule. In flexion, the range of adduction is still greater and is limited by the ischio-femoral ligament; the ligamentum teres is also rendered nearly tight.

In the nearly extended position, inward rotation is limited by the ilio-femoral ligament; and in flexion, by the ischio-femoral ligament, and the part of the capsule between it and the ilio-femoral ligament.

CHAPTER XVII.

THE KNEE-JOINT, OR
THE ARTICULATION OF THE FEMUR WITH THE TIBIA AND PATELLA.

Class, Diarthrosis. *Subdivision*, Ginglymus.

THE knee is the largest joint in the body, and the two longest bones of the skeleton enter into its construction. It is always, and rightly, described as a ginglymoid joint, but it is something more besides, for in addition to flexion and extension there is a sliding backwards and forwards of the tibia upon the condyles of the femur, and a rotation of the tibia around a vertical axis, permitted at the knee. It is also one of the most superficial, and, so far as relates to the bones alone, one of the weakest joints. There is no deep socket, as in the hip; no overhanging processes protecting it, as at the shoulder; no lateral buttresses, as at the ankle; no hook-like processes embracing the opposing bone, as in the elbow; no articular eminence, as in the jaw. The strength of the joint lies not therefore in the bones, but in the number, size, and arrangement of the ligaments which unite the bones, and in the powerful muscles and fascial expansions which pass over the articulation. By virtue of these structures it is one of the strongest joints in the body; is less frequently displaced than any other of the joints of the extremities; is capable of bearing immense weight; is constantly in action, enjoys a considerable range of movement, ,and yet has to withstand the leverage of the two longest bones. But its very complication of ligaments, which gives it its mechanical strength, is the cause of its liability to disease and of its constitutional weakness; whilst its scanty covering of soft parts, and its consequent superficial position, expose it more than any other joint to the injurious effects of blows and other violence.

Three bones enter into the construction of the knee-joint, viz., the femur, by its condylar end; the tibia, by its tuberosities;

and the patella. The adaptation of the articular surfaces of these bones to one another is so slight that in no position are they in more than partial contact; but yet it is so definite that the knee-joint may be said to consist of two articulations with a common synovial membrane, viz., the patello-femoral and the tibio-femoral, the latter being double. The articular surface of the femur presents a trochlea for the former, separated by two shallow oblique grooves from the two condyles which rest upon the latter, while the condyles are separated from one another by the inter-condyloid fossa.

THE FEMUR.—The lower or condyloid extremity of the femur is cubical and massive, although divided by a deep notch behind. It measures from three to three and a quarter inches in a transverse direction in its widest part, and nearly three inches in the antero-posterior. The transverse measurement increases from before backwards, owing to the divergence of the condyles behind. This divergence is more marked at the inner condyle, for whereas the outer border of the outer condyle is but little out of the line of the external surface of the shaft, the inner surface of the inner condyle projects from an inch to an inch and a half beyond the line of the internal surface of the shaft.

The external condyle is more prominent in front, and the internal somewhat more so behind. We must regard the bone from five aspects—in front, behind, below, and on each side. In front, the lower end of the femur is articular below the patella, and non-articular above, where it is pierced by numerous foramina for bloodvessels, and is rough for the attachment of the capsular ligament. The articular surface is irregularly quadrilateral, sometimes approaching more to a triangular outline; its outer border is the longest, and is prominent especially above; it separates sharply the front from the outer surfaces of the bone. The inner, short and placed upon the front of the inner condyle, is continuous with the upper border, and like it inclines outwards and upwards. The inner and upper borders divide the articular or patellar from the non-articular portions of the front surface of the lower end of the femur. The lower limit of the patellar facet is the inter-condyloid notch in the middle line; and two slight ridges with grooves behind them on the sides, which separate it the one from the inner, and the other from the outer condyle.

Looking at the bone from behind, we see immediately below the popliteal surface the rounded and prominent condyles projecting far back behind the line of the posterior surface of the shaft, and separated by the inter-condyloid notch, which is large enough to hold the ungual extremity of the thumb.

The floor of this notch is nearly on a level with the popliteal surface above, but becomes deeper as it inclines forwards below. It is rough and uneven for the attachment of the crucial ligaments. The condyles are rounded articular eminences, convex from side to side. Each forms from above downwards the arc of a circle, the extremities of which correspond pretty nearly with the superior and inferior limits of the inter-condyloid notch. Above the articular surface of the inner condyle is a depression for the origin of the inner head of the gastrocnemius; and above this again, and to its inner side, is the tubercle of the adductor magnus; here too terminates the inner condyloid ridge. Above the outer condyle the outer head of the gastrocnemius and the plantaris arise from a slight depression, and to the outer side of this the external condyloid ridge terminates.

From below we see the two condyles widely separated by the inter-condyloid notch; towards the front of the notch they converge somewhat as they approach the patellar facet. As we see them from this aspect the borders of the outer condyle are almost parallel, and nearly straight from before backwards; whereas those of the inner condyle are considerably curved, with the convexity inwards. The convexity of the outer border of the inner condyle is the result of the inter-condyloid notch encroaching on this condyle near its forepart.

Those borders of the condyles which bound the notch are shorter than the others, and do not descend to so low a level, a construction necessary for its adaptation to the spine of the tibia.

The condyles (as distinguished from the condyloid extremity) articulate with the tibia, and are separated from the patellar facet, which is seen on the front of the bone, by two faint ridges; sometimes there is a shallow groove behind each ridge. The ridge between the external condyle and patellar facet extends from the outer surface inwards, and slightly backwards to the inter-condyloid notch a little behind its anterior extremity. The ridge between the inner condyle and the patellar facet is situated more anteriorly, has a much more antero-posterior direction, and terminates behind at the anterior margin of the condyloid notch.

The outer surface of the condyloid extremity measures nearly three inches from before backwards, and one inch and three-quarters from above downwards. The anterior two-thirds is flat and smooth; posteriorly there is a deep and curved groove, which reaches from the upper part of the condyle behind to a spot very nearly on a level with the ridge where the condyle joins with the patellar facet; this is for the popliteus muscle. Above the popliteal groove, and rather behind the level of the posterior surface of the shaft of the femur, is an eminence to which is attached the external lateral ligament; above and behind this is a rough groove for the external head of the gastrocnemius.

The inner surface of the condyloid extremity is of about the same dimensions as the outer surface. It is convex from before backwards and from below upwards, not flat, like the outer surface. There is a faint groove posteriorly, taking the course of the border of the condyle, and above this groove and behind the line of the posterior surface of the shaft of the femur there is a prominent eminence, with a depression at its summit for the attachment of the internal lateral ligament.

THE TIBIA.—The upper extremity or head of this bone, like the lower end of the femur, is greatly expanded. It presents two tuberosities, the articular surfaces of which are separated by the spine of the tibia. It measures from two and a half to three inches transversely, and from one and a half to two inches antero-posteriorly. The antero-posterior measurement is greater on the inner than on the outer side.

The tuberosities considerably overhang the shaft of the bone behind and on each side, but especially behind. In front the surface recedes from the tubercle upwards. On this aspect we see, an inch and a half from the upper surface, and in a line with the crest or the shin of the tibia, a rough projection named the tubercle of the tibia, to the lower part of which the ligamentum patellæ is attached. Above this the bone is perforated by several large foramina. Running upwards from the shin to the outer side of the head is a well-marked ridge, to which are attached (1) a strong process of the fascia lata, which descends from the tensor vaginæ femoris, Looking at the bone from behind, we see immediately below the popliteal surface the rounded and prominent condyles projecting far back behind the line of the posterior surface of the shaft, and separated by the inter-condyloid notch, which is large enough to hold the ungual extremity of the thumb.

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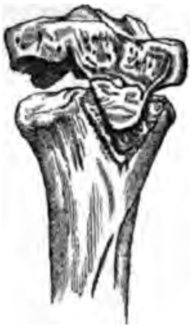
(2) some of the fibres of the vastus externus and its fascial expansion over the knee, and (3) close to the facet for the fibula, some of the fibres of the biceps tendon. Also connected with this ridge are the fascia of the leg, and the highest fibres of the tibialis anticus and extensor longus digitorum. The lower half of this ridge corresponds to the line of union of the epiphysis and shaft.

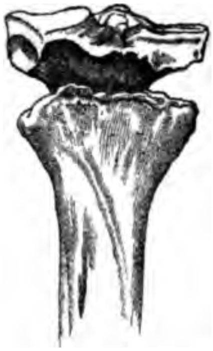
A similar curved line, slighter, but still well-marked, extends upwards from the tubercle to the inner tuberosity, as far as a rough surface at which part of the semi-membranosus tendon is inserted. It gives attachment to the vastus internus, and the fascial expansion over the inner side of the knee. It corresponds, like the external ridge, to the line of union of the epiphysis and shaft. (*Vide* Diagrams VII. and VIII.) These ridges, meeting below at the tubercle, limit a triangular rough surface which, in the recent subject, is occupied by a cushion of fat, upon which the synovial membrane of the joint is supported.

DIAGRAM VII.



Anterior view, left tibia.

DIAGRAM VIII.



Posterior view.

Behind, the head of the tibia overhangs the popliteal surface of the shaft; it has a well-marked border, varying from a quarter to half an inch in depth, interrupted in the middle by a notch, and limited below by a ridge which is continuous around the outer and inner tuberosities, with the ridges running upwards from the tubercle.

Above the ridge at the outer part of this surface is the articular facet for the head of the fibula, and above this again an oblique groove for the tendon of the popliteus muscle. Above the ridge on the inner side of this surface is the horizontal groove for the semi-membranosus muscle which extends some distance round upon the inner aspect of the head.

This encircling ridge, together with the whole of the oblique ridge between the tubercle and inner tuberosity, and the lower half of the oblique ridge from the tubercle to the outer tuberosity, marks the line of union of the shaft and upper epiphysis, and thus the facet for the upper end of the fibula belongs to the superior epiphysis of the tibia. (*Vide* Diagram VIII.)

Superiorly are seen the facets for the condyles of the femur, which in the recent state are deepened by the semilunar cartilages. The outer is nearly circular, being encroached upon on the fore and inner sides. The inner has a longer antero-posterior than transverse diameter, and is broader behind than in front; with the outer part of its circumference nearly straight it resembles the half of an ellipse. Around the circumferential part of each facet is a flattened border upon which rest the semilunar cartilages, and limiting this border is a sharp rim to which the coronary ligaments of the semilunar cartilages are fixed. The facets are but slightly cupped in the dry state; they are separated by an eminence—the spine—and by rough depressions in front of and behind the spine. The depression in front is the broader and longer of the two, that behind is the deeper, and is part of the popliteal notch seen on the posterior aspect of the head. Projecting upwards on the sides of the spine are two small tubercles, one of which forms part of the inner circumference of the outer facet; and the other, the more prominent of the two, part of the outer circumference of the inner facet, from which it rises abruptly upwards. Between the tubercles the spine itself is depressed. The spine stands up into the intercondyloid notch of the femur, and tends to prevent lateral, especially internal, displacement of the tibia.

THE PATELLA, or knee pan, is a sesamoid bone which articulates with the femur, and is attached to the tibia by the ligamentum patellæ. It is nearly circular in outline, but slightly prolonged below; it has two surfaces, an anterior and a posterior, and a well-marked border, which is thicker above and below than on the sides.

The anterior surface is subcutaneous and slightly convex; it is longitudinally grooved or striated by many fibrous bundles, which are continued from the quadriceps extensor tendon over the patella into the ligamentum patellæ.

The posterior surface is smooth and articular, and is divided into two facets by a prominent vertical ridge. This ridge increases considerably the thickness of the bone by adding to its substance along its centre.

As the patella plays over the femur it occupies the groove on the front of its condyloid extremity. The outer facet is much the larger, and is slightly concave both from above downwards and from side to side. The inner facet is convex from side to side, but slightly concave from above downwards. Two slight transverse ridges, which extend across the posterior surface, divide each of these facets into three parts, each slightly depressed. The superior ridge marks off rather less than one-third of the articular surface which articulates with the femur during flexion of the knee. The lower ridge marks off about one-sixth of the articular surface which is in contact with the upper part of the patellar facet of the femur in extreme extension. The large portion of the articular surface between the ridges rests against the femur in the mid-state between extension and flexion when there is the greatest strain upon the patella, and the bone thus requires the greatest support; a seventh area, narrow and vertical, upon which the transverse lines do not extend, is marked off upon the inner side of the inner facet, and this in extreme flexion rests upon the outer margin of the inner condyle of the femur. In extreme flexion the patella is gradually turned outwards by the increasing prominence of the inner condyle, and the slightly oblique plane in which the tibia is moved inwards in flexion. For this reason, as well as to resist the tendency of the patella to be pulled outward by the extra power of the vastus externus over the internus, the outer condyle of the femur presents a larger articular surface for the patella than does the inner.

The limiting margin of the articular surface marks off very sharply the facets from the border of the patella. Above, the border is very thick, and slopes downwards in front at the expense of the subcutaneous surface; it gives strong attachment to the quadriceps extensor femoris tendon in front, and support to a cushion of fat behind between the tendon and the articular surface. Below, the border is also thick, and extends upwards behind at the expense of the posterior surface, where it forms a rough depression. By its anterior lip it gives firm attachment to the ligamentum patellæ, and by the rough depression behind it supports a large cushion of fat which occupies the interval between the ligament below and in front, and the articular surface of the patella and synovial membrane of the joint above and behind. Laterally, the margins are comparatively thin, and give attachment to the expansions of the conjoined tendon of the extensor muscles.

The patella protects the front of the knee-joint during flexion, and for this purpose spreads out so as to cover the front of all the median part of the joint from the level of the inter-condyloid notch above to the fossa in front of the tibial spine below. In all positions of the joint it shelters the crucial ligaments. Its anterior surface is flattened to permit of kneeling, and in this position the patella transmits the weight of the body to the ground immediately from the femur, without any pressure being produced upon the soft inter-articular structures by the surface knelt upon.

It affords important leverage to the quadriceps extensor muscle, and by sliding up and down upon the trochlea of the femur it varies the amount of leverage it affords inversely with the increased or diminished advantage of the position of the joint itself.

In this way the patella adapts the extensor muscles to furnish force and velocity. In extension, while the patella is resting on the front of the femur and the ligamentum patellæ slopes forwards from the tibia to the patella, force but not velocity is required, as the muscles are in action not to set the leg in motion, but to keep it steady in a position already occupied; but in flexion, as the patella recedes into the space between the condyles and the tibia, and the ligamentum patellæ becomes parallel with the tibia, or even inclines a little backwards in extreme flexion, force is lost; but when the muscles act to restore the limb into the straight position, velocity is gained at the expense of force, owing to the greater obliquity with which the muscles now act on the tibia. The gradual transition from a leverage of velocity into one of force provides that the movement should become slower towards the completion of extension, and undue strain on the ligaments which stop extension is thereby prevented.

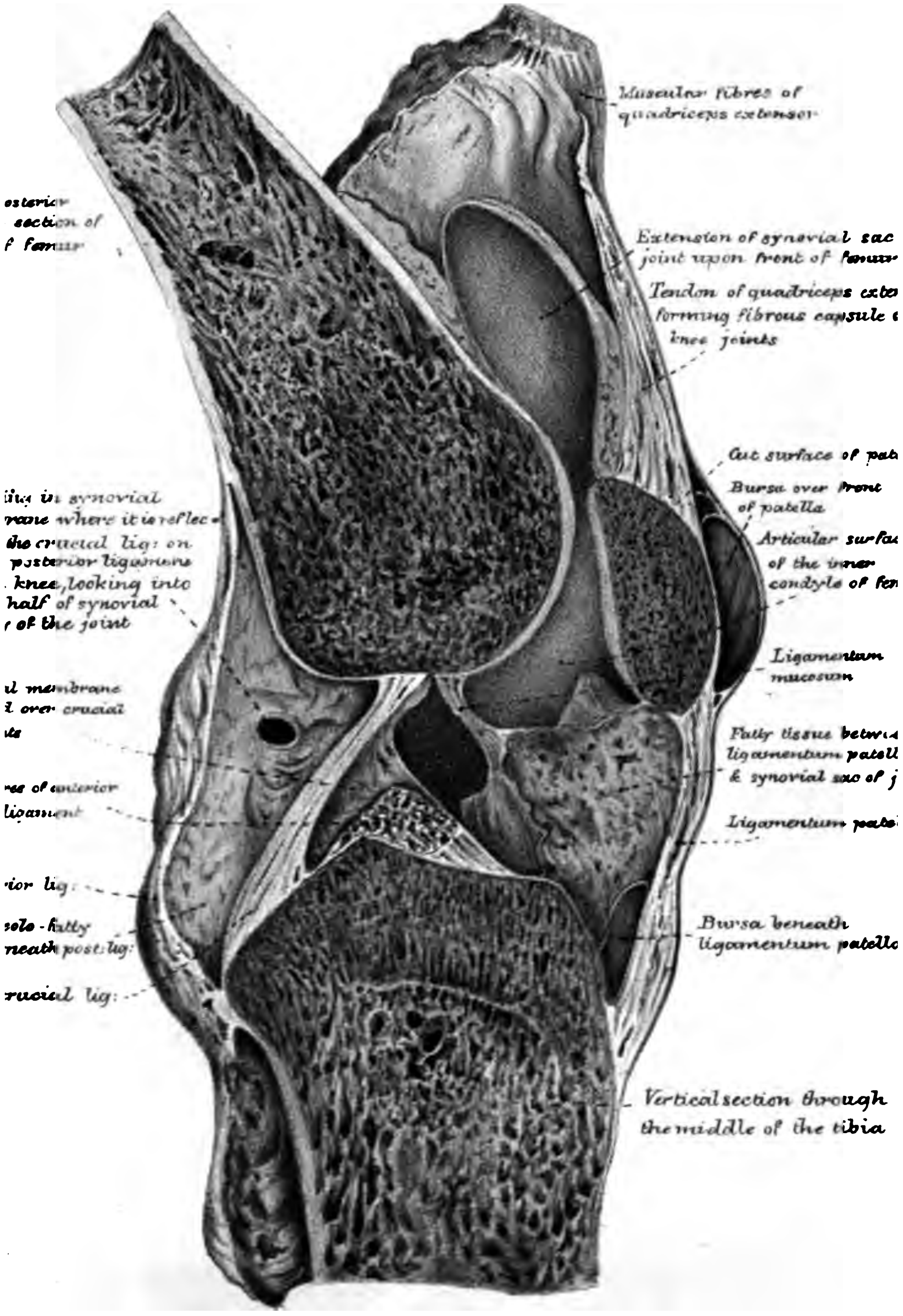
THE LIGAMENTS.—The femur is united to the tibia directly by five ligaments, viz., the two crucial within the joint, and the posterior and two lateral without; and indirectly (through the medium of the patella and quadriceps extensor tendon) by the ligamentum patellæ.

The patella is directly connected to the tibia by the ligamentum patellæ, which being inelastic and not contractile holds the patella always in the same relation to the tibia; whereas the patella is connected with the femur only through the tendon of the united extensor muscles, and varies its position with respect to the femur with all the movements of the tibia, some of which are effected by the contraction of these muscles themselves. It must be observed, however, that as the ligamentum patellæ is inelastic and not contractile, the extensor muscles can only alter the position of the patella by moving the tibia also.

The semilunar cartilages which deepen the facets of the tibia, and partially intervene between the femur and tibia, are united together by the transverse ligament, and to the tibia by the coronary ligament. Other ligaments are spoken of as entering into the formation of this joint, such as the alar ligaments and the ligamentum mucosum, but these are only reduplications of the synovial membrane and in no way give strength to the joint nor limit its movements

A very complete and capacious fibrous investment is formed by the lateral and posterior ligaments, together with the ligamentum patellæ, patella, and quadriceps extensor tendon. This investment is everywhere very thick and strong, and blended with and strengthening it behind are the tendons of origin of the gastrocnemius muscles, while the semi-membranosus tendon, after forming by some of its fibres part of the posterior ligament, disappears between the posterior and internal lateral ligament and passes across the deep surface of the latter. The fascia covering the popliteus muscle also blends with the posterior ligament, as well as with the lower and hinder part of the internal lateral ligament of the knee-joint. The muscle itself fills up the depression on the shaft of the tibia beneath the overhanging tuberosities, and its tendon of origin disappears im-

VERTICAL ANTERO POSTERIOR SECTION THROUGH KNEE JOINT



A. Hensman del. ad. nat.

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mediately above the head of the fibula beneath the posterior ligament. On the outer side the tendon of the biceps is closely connected with the external lateral ligament. Let us first understand the connexions of the several portions of this capsular investment.

The Fibrous Expansion of the Extensor Tendon.—The quadriceps extensor tendon, which extends for several inches along the front of the thigh, is a densely thick and strong structure, about one and a half inches broad. As it approaches the patella, it receives along each of its borders fresh tendinous fibres from the vasti and crureus, so that just above the patella we find the conjoined tendon consisting of a very thick and strong central portion, with a thinner but still strong lateral portion continuous with it on each side. This aponeurotic expansion of the tendon, together with the fascia lata of the thigh, covers the whole of the front aspect of the condylar portion of the femur.

The central portion of the tendon is inserted into the anterior two-thirds of the upper border of the patella, while many of its superficial fibres pass over the subcutaneous surface of that bone, and are continuous below it with the ligamentum patellæ. The lateral portions are similarly inserted into the upper border of the patella on each side of the thick central mass, as well as into the lateral borders of the bone (nearer the anterior than the posterior surface), as low down on each side as the attachment of the ligamentum patellæ. Still further outwards its fibres are attached to the oblique lines which extend upwards from the tubercle of the tibia to the inner and outer tuberosities, and thus reach as far as the internal and external lateral ligaments. On the inner side the fibres are prolonged below the oblique line, and, like the internal lateral ligament, become blended with the periosteum of the shaft. On the outer side, numerous well-marked fibres belonging to the fascia lata on the outer side of the thigh are prolonged downwards and inwards to reach the external oblique ridge of the tibia, and in their course blend with the expanded quadriceps tendon. These fibres are continuous with that portion of the fascia lata into which the tensor vaginæ femoris is inserted.

We have thus, in the conjoined tendon, a large hood spread over the whole of the front of the joint, surrounding the patella along the anterior margin of its border, and covering its anterior surface, but leaving its posterior surface and the posterior margin of the border of the patella free; while on the sides of the patella it reaches to the lateral ligaments of the knee. It is continued into the ligamentum patellæ in the middle line, and on each side is attached to the front surface of the tibia, as far out as the insertion of the lateral ligaments.

On the deep surface of the tendon, and between it and the lower end of the shaft of the thigh-bone, we have a large bursa, whilst the large and loose synovial membrane of the knee-joint extends upwards for some distance over the front of the condyloid extremity of the femur. This hood of fibrous tissue is, however, everywhere separated from the synovial membrane, which it protects by a layer of fat. This fatty tissue is of considerable thickness both above and below the patella, more especially in the middle line below it, where there is a large cushion or pad between the ligamentum patellæ and the synovial sac.

The *ligamentum patellæ* is simply the continuation of the central portion of the conjoined tendon. It is attached above to the lower border of the patella, and, as already mentioned, is continued over the front surface into the central portion of the quadriceps extensor tendon; below it is inserted into the lower part of the tubercle, as well as into the upper end of the crest of the tibia.

Its insertion into the tibia is very oblique, being prolonged much further down on the outer side, so that whereas along the inner border it measures about two and a half inches in length, it is fully one inch longer on the outer border. This mode of insertion, together with a corresponding obliquity in the surface of the tibia at this spot, causes the leg to be slightly rotated outwards in complete extension by the extensor muscles.

No effect is produced by this ligament in limiting flexion or other movements of the knee.

The *internal lateral ligament* is a strong flat band, which extends from the depression on the tubercle at the inner side of the internal condyle of the femur, to the inner border and inner surface of the shaft of the tibia, for an inch and a half below the head. It is three and a half inches in length, well-defined along its anterior edge, where it blends with the aponeurotic expansion of the conjoined tendon; not well-defined posteriorly, where it merges into the posterior ligament. The semi-membranosus muscle passes beneath it. It is firmly connected with the edge of the inner semilunar cartilage and with the coronary ligament, which binds that cartilage to the tibia. At its lower extremity some of its fibres are deflected into the descending portion of the semi-membranosus tendon. A twig of the inferior internal articular artery passes between the tendon and the ligament.

When the tibia, as in flexion, is brought into contact with the hindermost part of the condyles of the femur, the distance between the points of attachment of the lateral ligaments is reduced to its minimum, and the ligaments are relaxed; whereas, when the tibia is brought into contact with the fore part of the condyles, as in extension, the distance between the points increases until extension is complete, and the lateral ligaments are tightened. (*Vide* Diagrams on pages 375 and 376.)

The lateral ligaments are therefore quite relaxed during flexion of the knee, and do not interfere with any of the movements; but, as extension is made, they are gradually tightened, and in complete extension they hold the articular surfaces firmly together. They resist over-extension by not permitting the tibia to slide further forwards upon the condyles, nor any increase in the space between the hinder part of the articular facets of the tibia and the femur. During extension they resist rotation outwards of the tibia upon a vertical axis, by the oblique direction which the ligaments assume during extension, viz., the outer one slants backwards to the fibula, and the inner one forwards to the tibia.

The external lateral ligament consists of two distinct parts; the *anterior* is the best-marked and the longer of the two; it is attached above to the tubercle on the outer side of the external condyle, having the origin of the popliteus below and in front of it, and the origin of the outer head of the gastrocnemius above and behind. All three of these structures are close together, but the popliteal tendon is hidden from view until the capsule of the joint has been removed. Below, the ligament is fixed to the middle of the outer surface of the head of the fibula, half an inch or more anterior to the styloid process.

On the superficial aspect is the tendon of the biceps, which splits to embrace the ligament near its lower end; beneath it is the popliteal tendon contained in its sheath, and the inferior external articular artery. It is about two inches in length, and is not connected with the semilunar cartilage, nor with the tibia.

The *posterior* portion of the external ligament is one-third of an inch behind the anterior. Although broader, it is shorter and less defined. Below, it is fixed to the styloid process of the fibula; and inclining somewhat backwards as it passes upwards it ties down the popliteus against that part of the outer tuberosity which is immediately above and behind the facet for the head of the fibula. It blends with the posterior ligament beneath the outer head of the gastrocnemius muscle.

The external lateral ligament, like the internal, is tight in extension and relaxed in flexion. It checks over-extension of the knee in the same manner as does the internal ligament, and by the backward direction of its fibres during extension it limits rotation outwards of the tibia round a vertical axis. It has no influence over pronation and supination of the leg, as those movements only occur while the knee is bent, and consequently while the ligament is relaxed, and they are not more restricted before than after division of the ligament.

The external and internal lateral ligaments of the knee differ from the lateral ligaments of the true hinge-joints in being tense only in one position, instead of in every position of the joint.

The external lateral ligament differs from the internal in being rope-like instead of flat; it is freer from the joint, and not united to the semilunar cartilage or coronary ligament; and while it is attached to the femur on a little lower level than the internal, its connexion with the fibula is higher than that of the internal with the tibia, so that it is an inch, or more, shorter than the internal lateral ligament. Both ligaments have a special and peculiar relation to the tendons of muscles, the internal to the semi-membranosus, and the external to the popliteus and biceps.

The posterior ligament, or ligamentum Winslowii, is a broad, and for the most part a dense structure of interlacing fibres, with large orifices between them for the passage of blood-vessels. Its thinnest point is below the oblique fibres of the semi-membranosus tendon just opposite the popliteal notch in the border of the tibia. The tendon of the semi-membranosus muscle is so incorporated with it, that it is impossible to describe the ligament fully without also describing the tendon. Below the ligament, is the popliteus muscle, with the sheath of the tendon of which it is blended; above it are the origins of the gastrocnemius muscle.

It is attached to the femur close beyond the articular surface of the condyles, and between the condyles it stretches along the posterior and upper margin of the inter-condyloid notch. It reaches from the external to the internal lateral ligament. The outer head of the gastrocnemius and the plantaris are incorporated with it.

Inferiorly it is fixed to the border of the outer tuberosity of the tibia, to the bone below the popliteal notch, and to the shaft below the inner tuberosity of the tibia, where it is blended with the descending or vertical slip of the semi-membranosus tendon, and the internal lateral ligament.

On the superficial aspect of the ligament another slip of the semi-membranosus tendon is reflected upwards and outwards as far as the outer head of the gastrocnemius, forming a strong oblique band of union with the gastrocnemius; where it joins the gastrocnemius over the outer condyle there is sometimes a sesamoid bone developed. This slip vastly strengthens the posterior ligament, of which indeed, if not the chief constituent, it at least is an important part.

On its deep surface the ligament is closely connected with the back of the semilunar cartilages (but especially with the inner), as well as with the coronary ligaments; while in the interval between the cartilages it is inseparable from the dense mass of fibro-fatty tissue which fills up the part of the popliteal notch not occupied by the posterior crucial ligament; similar tissue fixes it to the inter-condyloid notch of the femur. In fact, although the ligament passes freely from femur to tibia over the condyles, it is firmly connected in the interspace with the posterior crucial ligament and fibro-fatty tissue within the joint; and it is the contraction of this tissue and of the posterior ligament which offers the chief resistance to extension in cases of fibrous ankylosis of the knee. The dissection of such an ankylosed knee in the dead-house proved that extension was resisted after division of all the other tissues around the joint except the posterior ligament, and the structures connected with, and extending forwards from its deep surface in the median plane of the joint.

The tendon of the semi-membranosus, which is such an important part of the ligamentum Winslowii, spreads out in three directions behind the inner tuberosity, but cannot be said to divide into three parts. Each portion blends with the posterior ligament. The oblique part has been specially referred to above, the anterior passes horizontally forwards beneath the internal lateral ligament, while the descending portion is blended with the lower and inner part of the posterior ligament, and then is attached to the tibia along the internal lateral ligament, with which also it is closely united.

The posterior ligament with the semi-membranosus tendon gives great steadiness and strength to the back of the knee-joint, and like the anterior portion of the capsule of the hip saves the necessity of muscular action in keeping the body erect. As the line of gravity falls through the knee a little in front of the bearing point of the femur on the tibia, the tendency of the weight of the body is to over-extend the knee. This tendency is resisted by all the ligaments of the joint, for all are made tense by extension, but especially by the ligamentum Winslowii. The practical result of this is that the knee is kept straight without the aid of muscles in such attitudes as the " stand-at-ease" position, when the weight is borne entirely by the bones and ligaments of the knee upon which one rests.

The Anterior Ligament.—It will have been understood from what has been said, that the aponeurotic expansion of the quadriceps extensor tendon, strengthened by the fascia lata of the thigh, together with the patella and ligamentum patellæ, form a strong continuous investment for the front of the knee-joint; and also that these structures, together with the lateral and posterior ligaments, close the knee-joint below, on the sides, and posteriorly. It remains to be seen, however, how the joint is closed in anteriorly above the patella; how in fact the joint is shut off from the under surface of the extensor muscles of the thigh and the lower end of the shaft of the femur. After dissecting down the conjoined tendon and the fatty tissue beneath it, a thin but strong and very distinct membrane is exposed, which looks like a loose sac or bag between the patella and the front of the femur. This membrane stretches from the outer side of the external to the inner side of the internal condyle. Above, it is attached to the femur at a varying distance from its articular surface, for whilst it is often only a few lines above the inner margin of the inner condyle and the inner half of the patellar facet on the femur, it is fixed fully half an inch above the outer portion of this facet, and still further from the outer border of the external condyle. Below, it is connected with the upper and lateral borders of the patella near to its articular facets, and with the front border of the head of the tibia. On the outer side it spreads beneath the anterior portion of the external lateral ligament, and blends with the sheath of the popliteus tendon. On the inner side of the joint it joins the internal lateral ligament. The synovial membrane lines its deep surface and holds it against the borders of the semilunar cartilage, and it is also attached to the coronary ligaments. On its superficial aspect it is strengthened, between the femur and patella, by the thin expansion from the subcrureus muscle, and over this a quantity of fatty tissue is interposed between it and the expansion of the quadriceps extensor tendon. Adipose tissue and a bursa separate it from the ligamentum patellæ.

We have now seen how the articular surfaces of the bones and the synovial membrane of the knee are covered in by the following *external ligaments*:—1. The ligamentum patellæ; 2. The ligamentum Winslowii; 3. The internal lateral; 4. The long and short external lateral; 5. The anterior. We have next to examine the *internal ligaments*, some of which are fibrous, others composed merely of synovial membranes, and the fibro-cartilages, all of which are enclosed by the above.

The ligaments within the joint are the following:—1. The anterior or external crucial; 2. The posterior or internal crucial; 3. The transverse; 4. The coronary; 5. The ligamentum mucosum; and 6. The alar. Lastly, there are the internal and external semilunar fibro-cartilages.

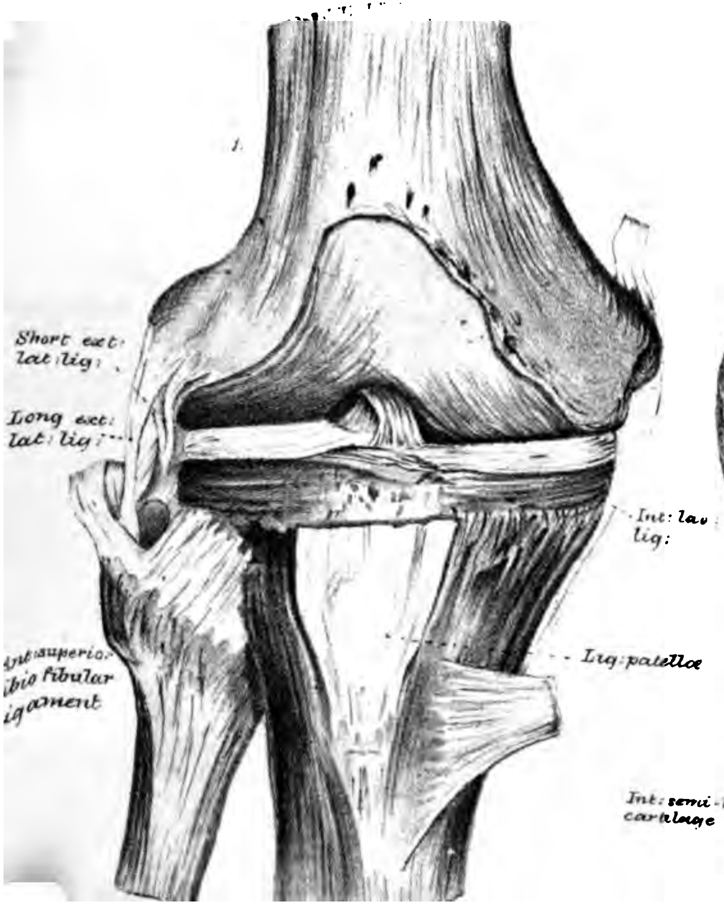
The two crucial, like the lateral ligaments, are attached one to each of the condyles, and being tense, or nearly so, in every position of the knee, may be compared with the lateral ligaments of true hinge-joints.

The *anterior crucial ligament* is attached to the inner half of the fossa in front of the spine of the tibia, behind the line of the transverse ligament; and to the outer border of the articular facet for the inner condyle, as far back as the inner tubercle of the spine of the tibia; near this tubercle it sometimes sends off a distinct slip into the posterior crucial ligament. It passes upwards, backwards, and outwards to the posterior part of the outer margin of the inter-condyloid notch; or, in other words, it is attached to the back part of the internal surface of the external condyle of the femur. Its connexion with the tibia is between the anterior horn of the internal semilunar fibro-cartilage which is in front of it, and the anterior horn of the outer semilunar cartilage, which for the most part is behind and to the outer side of it, but some few fibres of this cartilage split off from the rest and are attached in front of its outer edge. The component fibres of the anterior crucial ligament are not parallel nor of equal length; those which are in front at the tibia are the longest, are attached the highest on the femur, and are also the strongest. The posterior fibres are shorter and more oblique, and spring from the spine of the tibia.

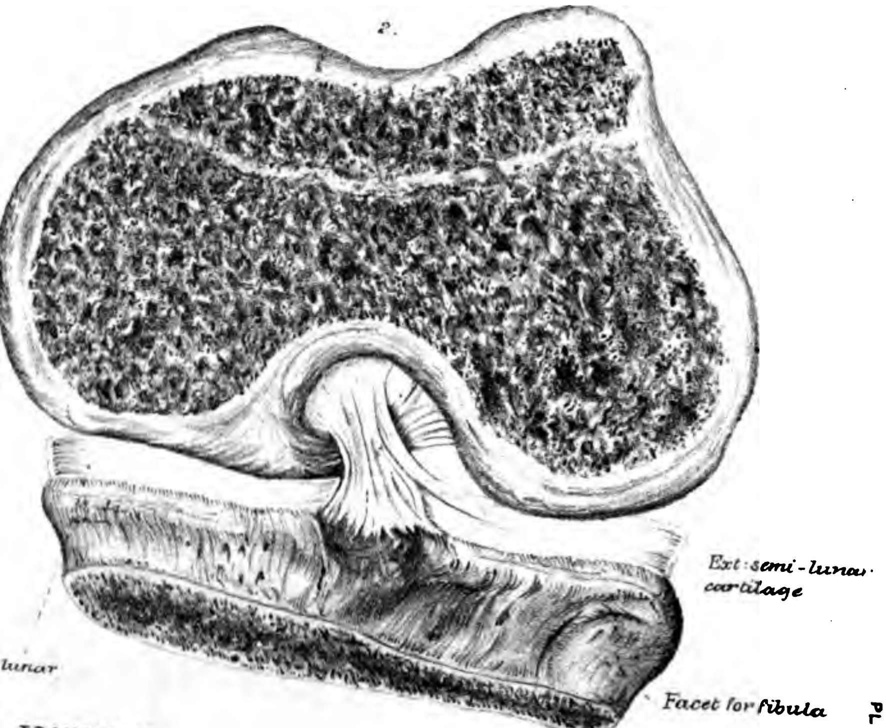
The anterior crucial ligament resists forward displacement of the tibia, and limits extension. In full extension all its fibres are on the stretch. As the knee passes from the extended into the bent position the ligament becomes gradually relaxed, *i.e.*, first the short posterior and then the long anterior fibres yield a little; but the degree of relaxation is never great, being indeed only just sufficient to allow of a slight inward rotation of the tibia upon the condyles round a vertical axis, *i.e.*, of pronation. During extension this movement is impossible, as the anterior crucial together with the lateral ligaments combine to prevent it. It has no influence in limiting flexion of the knee. Its action is best shown in a negative manner, *i.e.*, by cutting it across whilst the posterior crucial ligament is left entire; it will be then seen that the head of the tibia can be brought in front of the lower end of the femur in the half-bent position of the joint, but it cannot be put further back than before the ligament was divided.

The *posterior crucial ligament* is attached to the greater part of the fossa behind the spine of the tibia, but especially to its outer and posterior portion; it then passes upwards and inwards along the posterior spinous notch (which slopes in correspondence with this obliquity of the ligament), and after being joined by many scattered fibres which arise from the depres-

FRONT OF KNEE SHOWING ANTERIOR CRUCIAL LIGAMENT



POSTERIOR CRUCIAL LIGAMENT



TRANSVERSE SECTION THROUGH CONDYLAR
OF FEMUR

PLATE

sion between the tubercles of the spine of the tibia, it ascends to the outer surface of the inner condyle and the forepart of the inter-condyloid notch, where it has a wide and crescentic attachment, more than half an inch in extent, just above the edge of the articular surface. The fibres of the ligament have a cross arrangement; thus those which arise from the external and posterior part of the fossa of the tibia pass upwards to be fixed to the side of the condyle, whilst those attached to the tibia, on the inner side and in front of the former, are fixed to the femur at the forepart of the inter-condyloid notch.

It is connected along its posterior surface below directly with the ligamentum Winslowii; and indirectly, higher up, by means of a quantity of areolar tissue interposed between the two structures. Some of the posterior fibres of the posterior crucial ligament curve upon themselves near the outer tuberosity of the tibia, and blend with the ligamentum Winslowii as they pass upwards and outwards in that structure; while others curve forwards at the same spot, and are lost in the back part of the external semilunar cartilage. In this way the posterior crucial ligament may be said to fix the outer fibro-cartilage to the back of the joint. In front, the ligament, as it slopes upwards in the notch behind the tibial spine, rests on the posterior horn of the internal semilunar cartilage, and blends with the posterior horn of the outer cartilage. Still further forwards, and therefore further upwards, it is connected with the lower part of the anterior crucial ligament.

Until they rise above the level of the spine of the tibia, the two crucial ligaments are closely bound together, so that no interspace exists between their tibial attachment and their point of decussation. Each ligament, for some little distance from its tibial origin, rests upon the bone; the anterior inclining backwards and outwards, and the posterior straight forwards towards the anterior: but as soon as they ascend from the surface of the tibia they are bound together, and remain united until they cross each other. The only interspace between the ligaments is therefore a V-shaped one, *i.e.*, one corresponding to the upper half of their X-shaped arrangement. Even this, in the undissected state, is diminished to a mere chink, and can be seen from the front only, owing to a quantity of fatty tissue beneath the synovial membrane which surrounds their attachment to the femur.

From behind, even this chink cannot be seen until after the removal of the areolar or fibro-fatty tissue which mats the ligamentum Winslowii with the posterior crucial ligament and the posterior border of the semilunar cartilage, and fills up the inter-condyloid notch.

The posterior crucial ligament resists backward displacements of the tibia, and tends to limit flexion. In extreme flexion the tibia slides backwards beneath the condyles, and the ligament in consequence becomes tight. It has no effect in checking rotation, either outwards or inwards. Inward rotation is checked by the anterior crucial, but outward rotation, owing to the direction of the decussation of the ligaments, is not checked by either. When the other ligaments of the joint are divided, but the crucial left intact, outward rotation can be continued till these ligaments uncross, and the tibia is turned hind-foremost.

The posterior crucial is stronger and less oblique in direction than the anterior ligament; and it needs to be so, because the flexor tendons which it resists have a more direct and powerful influence on the tibia than the extensor muscles, whose tendon is attached firstly and largely into the patella. The action of the flexors upon the tibia is greatest when the knee is bent, and all the fibres of this ligament are rendered tense by flexion; but it is only in the dissected joint that the ligament can be said to actually *limit flexion*, for in the living, the soft parts of the popliteal region interfere to check the movement before the ligament is tight enough to do so.

In the slightest degrees of flexion the ligament is a little relaxed, but in extension all its fibres are tense; they would not permit of full extension if it were not for the sliding forwards of the tibia upon the femur in the extension movement. Thus the simultaneous movements of the joint exert counteracting influences upon the ligament; for while the forward sliding of the tibia in extension somewhat relaxes the fibres of the ligament, so in the same proportion does the turning of the hinder edge of the tibia away from the femur tighten them. Conversely, flexion by depressing the anterior edge of the tibia, and turning it away from the femur, would tighten the anterior ligament, so that flexion could not take place without being accompanied by sliding of the tibia backwards; nor could this sliding of the tibia backwards in flexion take place, unless at the same time the posterior edge of the tibia was turned upwards towards the femur; nor, again, would the sliding forwards of the tibia in extension, which is required by the conditions of the posterior crucial ligament, be permitted by the anterior, unless at the same time the tibia rotated on the transverse axis through its superior articular surface, so as to bring its anterior edge towards the femur.

Thus the crucial ligaments are so adapted to the articular surfaces, that while they possess all the advantages of lateral ligaments to hinge-joints, by maintaining a nearly uniform tension in all positions of the joint, they do not restrict the movements of the knee to simple flexion and extension.

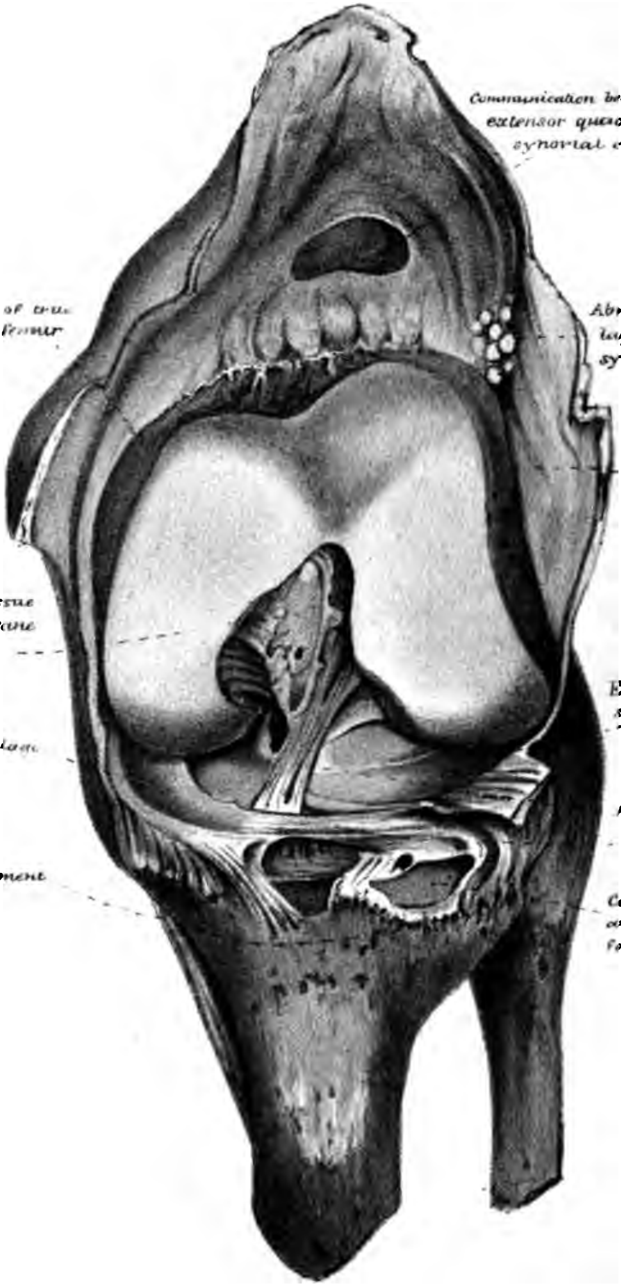
The inter-articular, or semilunar, fibro-cartilages are two crescentic plates resting upon the circumferential portion of the articular facets of the tibia, and moving with the tibia upon the femur. They somewhat deepen the tibial articular surfaces, and are dense and compact in their structure, except near their extremities, where they become looser and more fibrous. They are firmly fixed in front and behind the spine of the tibia, and somewhat loosely attached all around by the reflection from off their surfaces of the synovial membrane, as well as by the coronary ligaments which fix them to the borders of the tuberosities of the tibia. They leave uncovered more than one-third of each of the articular facets of the tibia. In width (as measured on their upper surfaces) each fibro-cartilage tapers somewhat towards its cornua; the outer somewhat more than the inner. At their widest part they are from one-half to five-eighths of an inch across; the widest part of the outer is in front of the external lateral ligament, the widest part of the inner is behind the internal lateral ligament. Owing to a slight bevelling off of their margins the upper surfaces are rather narrower than their lower. The circumferential border of each is convex, and from one-eighth to one-fourth of an inch deep; the inner border is concave and free, and not thicker than good thick note-paper; the thickness diminishes gradually from the outer to the inner border; they are thicker, *i.e.*, deeper, behind than in front. Their lower surfaces are flat, their upper slightly concave, owing to the sudden increase in the depth of the cartilages close to their outer margin. In outline each is adapted to the shape of the tuberosity upon which it rests, so that the outer is somewhat more circular than the inner, and forms almost a complete circle.

The outer semilunar cartilage is somewhat less fixed than the inner, and consequently can slide more freely backwards and forwards upon the articular facet of the tibia; its anterior cornu is attached to the deep and narrow depression in the anterior fossa along the outer articular facet, and just in front of the external tubercle of the tibial spine. Its attachment is close to, and on the outer side of, the tibial origin of the anterior crucial ligament, and the loose fibrous tissue of the cornu generally splits, so as to send forwards a slip to be connected with the tibia in front of the crucial ligament. The posterior cornu is attached firmly to the tibia behind the external tubercle, and blends very intimately with the fibrous tissue in the posterior fossa of the tibia, and through this with the posterior crucial ligament. It also sends forwards a narrow but well-marked slip into the back and lower part of the anterior crucial ligament. The cornua of this cartilage are separated only by the outer tubercle of the spine of the tibia. The outer margin is grooved towards its posterior part by the tendon of the popliteus muscle, which is held to it by fibrous tissue and synovial membrane, and separates it from the external lateral ligament. Attached to the anterior border of the fibro-cartilage is the transverse ligament.

The inner semilunar cartilage, owing to the shape of the inner tuberosity and to the wider points of attachment of its cornua, is a segment of a larger circle than the outer, or, more properly speaking, has an outline more oval than circular. Its anterior cornu, which is wide and seen completely only after cutting through the cartilage and turning it forward, has a broad and oblique attachment to the anterior margin of the head of the tibia. It reaches backwards and outwards from the margin of the tuberosity towards the middle of the fossa in front of the tibial spine. It is altogether in front of the anterior crucial ligament, the attachment of which to the tibia is between it and the anterior cornu of the outer cartilage.

Its posterior cornu is also firmly fixed to the tibia by a broad insertion, which extends in an antero-posterior line along the inner side of the posterior fossa, from the internal tubercle of the spine to the posterior margin of the head of

VIEW OF FRONT OF KNEE JOINT AFTER RAISING CAPSULAR LIGAMENT & CUTTING AWAY THE LIGAMENTUM MUCOSUM



A. Hensman del. ad nat. West, Newman & Co. lith.

the tibia. It is firmly connected with the posterior crucial ligament, and with the fibrous tissue in the fossa of the tibia. The posterior crucial ligament is attached to the tibia on its outer side, and behind it reaches down somewhat lower into the popliteal notch. Its convex border is connected with the internal lateral ligament and the tendon of the semimembranosus muscle.

Neither cartilage can be satisfactorily examined except by raising it from the tibia after dividing the coronary ligament.

The purposes served by the semilunar cartilages are, *first*, to interrupt shocks or jarring vibrations, which but for them would be transmitted from the leg to the thigh, not only in jumping or stamping, and such like actions, but even in walking and running; *secondly*, they serve to fill the angular intervals between the articular surfaces of the femur and tibia, which sometimes, as during extension, are but slight, but at others, as during flexion, are considerable; *thirdly*, they deepen the facets of the tibia for the condyles; and to serve this latter purpose they are less fixed at their forepart than behind, so as to be able to close in upon the spherical portions of the condyles in flexion, and to slide forwards and be squeezed out into large circles by the anterior nearly flat portions of the condyles in extension. This adjustment of the fibro-cartilages to the condyles of the femur in the varying positions of the joint is due partly to their own tendency to shift, partly to their connexions, and partly to the pressure and pull of surrounding parts.

In flexion and extension the cartilages move with the tibia upon the femur. In supination and pronation the tibia moves upon them while they remain unaltered in their position to the femur; the outer cartilage is steadied chiefly by the pressure of the popliteus (which is the muscle chiefly concerned in rotating the tibia inwards, *i.e.*, in pronating the leg) against the outer margin of the cartilage, whilst it is acting upon the tibia.

The transverse ligament is a rounded slender short cord, which extends between the front of the convex border of the external semilunar cartilage and the concave border or anterior cornu of the inner cartilage, near which it sometimes dips downwards to be attached to the fossa in front of the spine of the tibia. It is situated immediately beneath the synovial membrane, and is best seen after laying open the front of the joint by detaching the ligamentum mucosum from the femur as far as its base on the infra-patellar fat. It is a mere accessory band of the external cartilage.

The purpose of this ligament is to keep the semilunar cartilages in their due relative positions to one another, and it is especially of use in preventing the anterior portion of the external cartilage, which slides so much more freely upon the tibia than does the inner, from being displaced outwardly.

The coronary ligaments.—This name is given to the structure which attaches the semilunar cartilages to the head of the tibia. Were it not for these so-called ligaments there would be nothing to prevent the cartilages from being moved freely away from the borders of the tuberosities. In reality they are nothing more than the connexion between the margin of the inter-articular cartilages and the fibrous envelope of the joint, such as is found in each of the joints of the body which possesses an inter-articular fibro-cartilage. As in other joints, so in the knee, there is a synovial space on each surface of the cartilage, but those of the knee differ apparently from other inter-articular fibro-cartilages by being fixed at their cornua into the articular extremity of the tibia. This difference, however, is not real, for the fossæ and spine of the head of the tibia form a non-articular space between the two articular facets, and are indeed one of the limits of each of those facets, and therefore the attachment of the cornua of the fibro-cartilages to them is in no way different from the attachment of the cartilage of the sterno-clavicular joint to the clavicle above and the costal cartilage below; or of that of the radio-carpal joint to the styloid process of the ulna and the edge of the articular surface of the radius. These coronary ligaments are not in reality separate structures, but consist of the several ligaments which are connected with the rim of the cartilages as they pass over them to be attached to the head of the tibia. Thus in front on each side of the median line the anterior ligament; on the inner side, the internal lateral ligament; on the outer side, the sheath of the popliteus muscle; and behind, on either side of the popliteal notch, the ligamentum Winslowii enter into their construction.

The external coronary ligament is much more lax than the internal, so that the external cartilage can be raised higher from off the tibia—as high as three-eighths of an inch. In doing so the fossa, both in front of and behind the spine of the tibia, is exposed. On raising the inner cartilage the inner border of the anterior fossa is scarcely uncovered, though part of the posterior fossa is exposed. This loose attachment of the outer semilunar cartilage permits of it changing its position more freely than the inner, in the flexion and extension movements of the joint.

The synovial membrane of the joint dips downwards between the under surface of the external semilunar cartilage and the outer tuberosity of the tibia as low as the superior tibio-fibular ligament, and in doing so stretches nearly as far towards the middle line as the popliteal notch; in this way it forms a bursa in connexion with the joint, over which the popliteus plays at the back of the tibia.

The Alar Ligaments.—After laying open the synovial sac in front, and drawing down the patella and capsule, and then flexing the tibia acutely upon the femur, there is seen passing backwards from the capsule, near the sides of the patella, a prominent crescentic fold or wing on each side, formed by a doubling upon itself of the synovial membrane. These are the alar ligaments. Their free margin is concave and thin, and curves downwards and backwards upon the mass of fat below the patella, until it is lost in the ligamentum mucosum. Each has a pouch or fossa above and below it, the one above being bounded along the middle line by the synovial membrane as it passes backwards from the apex of the patella, to form the upper margin of the ligamentum mucosum.

The Ligamentum Mucosum.—This so-called ligament is the central portion of the large process of synovial membrane, of which the alar ligaments form the lateral free margins. It extends from the infra-patellar fat backwards and upwards to the inter-condyloid notch of the femur, where it is attached in front of the anterior crucial, and to the outer side of the posterior crucial ligament. Near the femur it is thin and transparent, consisting only of a double thickness of the synovial membrane, but near the patella, *i.e.*, at its base, the layers of synovial membrane contain between them some of the fatty tissue of this part of the joint. It is deeper from before backwards near the femur than elsewhere, and measures three-quarters of an inch in this direction. It is attached along nearly the whole antero-posterior distance of the inter-condyloid notch, and is separated from the posterior crucial ligament on the inner side, and from the inner surface of the external condyle on its outer side, by a small fossa or recess. Near the patella the ligament is wider from side to side than elsewhere, but not so deep from before backwards as it is above by a quarter of an inch. Its anterior or upper edge is free, and fully one inch long; its posterior edge is attached above by the reflection of its layers on to the crucial ligaments at the inter-condyloid notch, but is free below. It is not more than half the length of the anterior edge.

From off the sides of the ligament, both above and below the alar ligaments, there are often little processes or fringes of synovial membrane, which sometimes attain to a large size, and in a diseased state develop into melon-seed-like solid bodies.

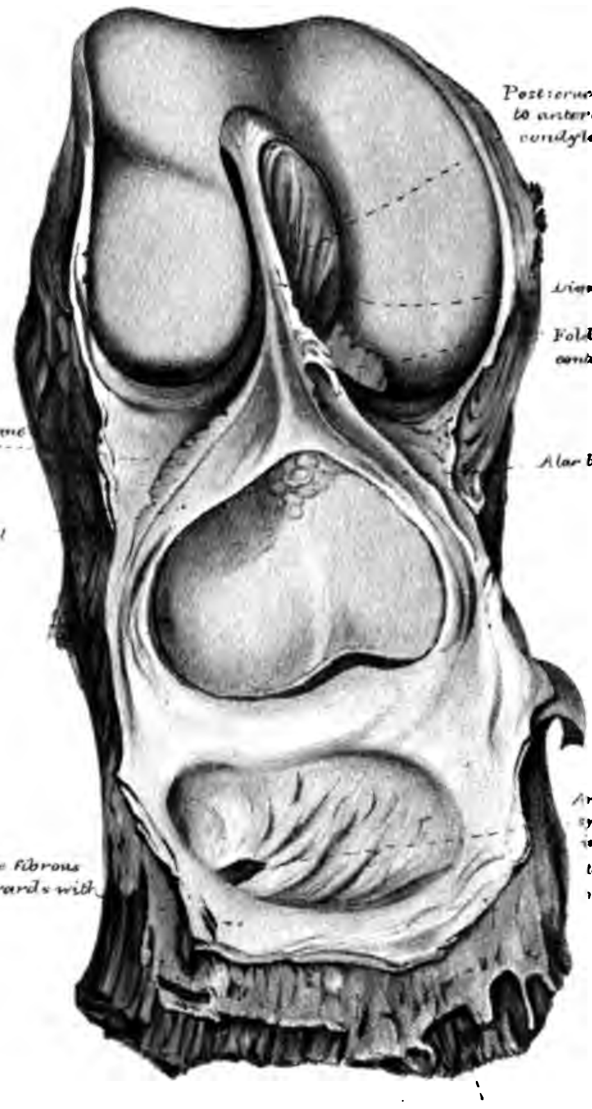
THE SYNOVIAL MEMBRANE of the knee forms the largest synovial sac in the body. It bulges upwards, following the capsule of the joint, into a large cul-de-sac beneath the extensor tendon on the front of the femur, which reaches some distance beyond the articular surface of the bone, and communicates most frequently with a large bursa, interposed between the tendon and the femur above the line of attachment of the anterior ligament.

After investing the circumference of the lower end of the femur, it is reflected upon the fibrous envelope of the joint formed by the anterior, posterior, and lateral ligaments. It passes also over the greater portion of the crucial ligaments; but the posterior surface of the posterior ligament, which is connected by means of fibro-areolar tissue to the front of the ligamentum posticum, and the lower portions of both crucial ligaments, where they are united together, of course cannot receive a complete covering from the membrane. The crucial ligaments, though partially enveloped by it, are of course shut out from the synovial cavity, like the tendon of the biceps from the shoulder-joint, the testicle from the tunica vaginalis, and the intestines from the peritoneum.

Along the above structures the synovial membrane is conducted to the semilunar cartilages, over both surfaces of which it passes, and thence along the inner surface of the coronary ligaments to the head of the tibia, around the

PLATE XXXV.

RONT VIEW OF KNEE JOINT AFTER DETACHING CAPSULAR LIGAMENT BY CUTTING ACROSS THE QUADRICEPS EXTENSOR OF THE LEG


Post: crucial ligament attached to anterior part of inner condyle
Ligamentum mucosum.
Fold of synovial membran containing fat
of synovial membrane ining fat
Alar ligament
Alar ligament
Artificial opening from synovial cavity of join into bursa between thigh & extensor muscle
rior portion of true fibrous sule thrown downwards with nsor muscle
Fibres of quadriceps extensor muscle.

A Hensman. del ad nat.
West Newman & Co lith.

circumference of which it extends a short way. It sends a pouch downwards between the external semilunar cartilage and the head of the tibia, to form a bursa for the play of the popliteal tendon.

At the back of the articulation, two pouches are prolonged beneath the muscles, one on each side, between the condyle of the femur and the origin of the gastrocnemius. Large processes of the synovial membrane also project into the joint, and being occupied with fat, serve as padding to fill up spaces. The chief of these is situated upon the infra-patellar fatty mass, and from it the ligamentum mucosum springs. Another and more slightly marked pouch often exists around the patella, and from it arise the alar ligaments.

ARTERIES.—The knee-joint is supplied with blood from the femoral, popliteal, and anterior tibial vessels.

From the femoral, the anastomotic artery, a branch of the femoral, supplies the capsule on the inner side, where it anastomoses with the superior internal articular branch of the popliteal and with the recurrent branch of the anterior tibial. A branch of the anastomotic crosses the femur obliquely in the substance of the vastus internus muscle, and forms an arch with the superior external articular artery on the upper part of the capsule of the joint, through which it sends offsets into the articulation.

From the popliteal artery five articular vessels are given off; two arise above, two below, and one opposite to the line of flexure of the joint. *The superior, internal, and external articular* arteries wind round the femur, keeping close to the bone above the inner and outer condyle respectively. On the front of the femur each divides into two branches, one of which is somewhat more superficial than the other, and ramifies in the fibres of the extensor muscles; the other ramifies on the front of the femur and in the capsule of the joint. The vessels of opposite sides anastomose with each other, with the anastomotic of the femoral trunk, and with the inferior articular branches of the popliteal.

The *inferior internal articular artery* passes downwards between the internal tuberosity of the tibia and the internal lateral ligament of the joint. It is distributed on the front and inner side of the articulation.

The *inferior external articular artery* curves forwards on a higher level than the inferior internal articular artery, being above the head of the fibula. It passes beneath the outer head of the gastrocnemius, the tendon of the biceps, and the external lateral ligament of the joint. It divides on the outer side of the patella into branches which supply the joint and anastomose with the corresponding vessel of the opposite side, with the recurrent branch of the anterior tibial, and with the superior external articular vessel.

The *azygos artery* pierces the posterior ligament, and supplies the crucial ligament and the structures filling up the inter-condyloid notch. This branch frequently arises from one of the superior articular vessels, especially the external; sometimes there are two or three small branches piercing the posterior ligament.

From *the anterior tibial artery* the *recurrent* branch is given off as soon as it pierces the front of the leg. After ascending between the fibres of the tibialis anticus it is distributed to the knee-joint on the outer side of the patella, where it anastomoses with other articular branches, especially with the inferior external articular of the popliteal.

THE NERVES.—The knee-joint, by its nervous supply, is brought into connexion with both the sacral and lumbar plexus. With the former, through both the external and internal popliteal branches of the sciatic nerve; with the latter, through branches of the anterior crural and obturator nerves.

Sciatic Source.—The *internal popliteal* nerve supplies two, and very often three, branches to this joint. One follows the course of the azygos artery, and enters the joint through the posterior ligament; another accompanies the inferior internal articular artery; and a third very frequently runs with the superior internal articular vessel, and enters the joint with it.

The *external popliteal* nerve gives two branches to the joint; they are often united at their origin, but the superior sometimes arises from the trunk of the sciatic. They follow the course of the superior and inferior external articular arteries respectively.

The *recurrent articular branch* of the external popliteal nerve arises just above the bifurcation of the trunk into musculo-cutaneous and anterior tibial; it takes the course of the recurrent articular branch of the anterior tibial artery, and passes with it through the tibialis anticus muscle to the forepart of the knee-joint.

Anterior Crural Source.—The *nerve to the vastus internus* sends an offset to the knee-joint, which perforates the capsular ligament on the inner side, and runs outwards on the synovial membrane as far as the ligamentum patellæ. It descends to the knee with a branch of the anastomotic artery along the internal inter-muscular septum. The *nerve to the vastus internus* sends an articular branch to the joint, which passes the capsule on the outer side.

Obturator Source.—The posterior or deep portion of this nerve sends an articular branch to the knee. It is deeply placed in the thigh, descends upon, and afterwards passes through the fibres of the adductor magnus muscle to reach the upper part of the popliteal artery. Having reached the back of the knee-joint, the nerve enters it through the ligamentum Winslowii.

BURSÆ.—The bursæ in the neighbourhood of the knee-joint are situated on the anterior and posterior aspects of the articulation. There is also a large bursa on the forepart of the tibia below the inner tuberosity, over which the tendons of the sartorius, gracilis, and semi-tendinosus pass before being inserted into the tibia. This, however, can scarcely be said to be in the immediate neighbourhood of the knee-joint.

On the front aspect of the knee-joint there are three bursæ.

1. One, large and superficial, is placed between the patella and ligamentum patellæ behind, and the subcutaneous tissue in front. This is the bursa which so frequently inflames and enlarges, and when enlarged is familiarly spoken of as the "housemaid's knee." It might as appropriately be styled the "devotional or the suppliant's knee," as there is a tendency for it to become large in any one who kneels frequently and long.

2. Another bursa is situated behind the tendon of the extensor muscles of the leg, between it and the front of the femur. The wall is closely connected with the capsule of the knee-joint by a little cellular tissue, and its cavity is frequently in communication with the synovial cavity of the knee-joint.

3. A third bursa is placed behind the ligamentum patellæ,

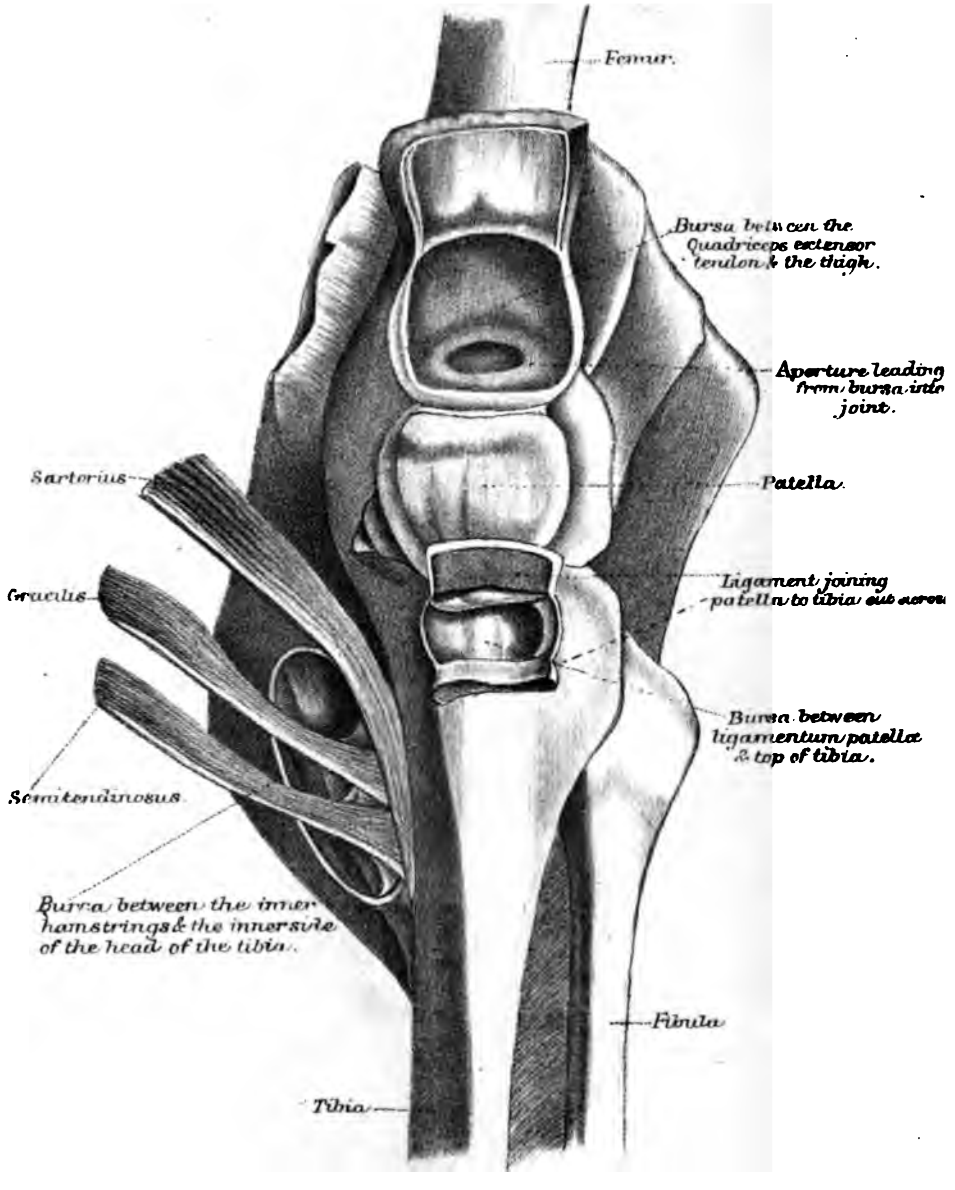
and between it and the forepart of the head of the tibia. It is not in communication with the joint, but is separated from it by the mass of fatty tissue behind the patella. The upper part of this mass is covered by the synovial membrane of the knee-joint and the under part of it by the wall of the bursa, which it somewhat invests so as to encroach upon the bursal cavity.

The bursæ behind the knee are contained in the popliteal space. They are of two distinct kinds, (1) those over which the tendons of muscles glide; and (2) those occasionally found between the back of the joint and the popliteal vessels, which are either new formations or herniæ of the synovial membrane. These latter are sometimes attached by a pedicle to the posterior ligament, and sometimes communicate with the synovial cavity; it is not necessary to do more than refer to them, as they have no constant existence.

The former, from their connexion with the tendons of muscles, are necessarily situated along the internal and external borders of the space. On the inner border there are two bursæ—one placed between the internal condyle, on the one hand, and the internal head of the gastrocnemius and the semi-membranosus, on the other; it sends also a process between these two muscles. This is the largest of the popliteal bursæ, and reaches from the posterior inferior part of the internal condyle of the femur to the back of the inner tuberosity of the tibia, as low down as the upper border of the popliteus muscle. Its inner border extends beneath the semi-membranosus tendon; its external border does not normally project beyond the inner head of the gastrocnemius. Occasionally it is divided into two parts, more or less completely: one portion for the gastrocnemius, and the other for the semi-membranosus. In adult life and in old age it generally communicates with the cavity of the knee-joint, either directly or through a secondary bursa contained within it. From its size, its constancy, the frequency with which it is in connexion with the joint, and its proneness to enlarge—sometimes alone, sometimes in association with synovial effusion into the joint—it is the most important of the hamstring bursæ. The second bursa proper to the semi-membranosus is situated obliquely, close to the insertion of the muscle, and separates the anterior surface of the tendon from

PLATE XXXVI.

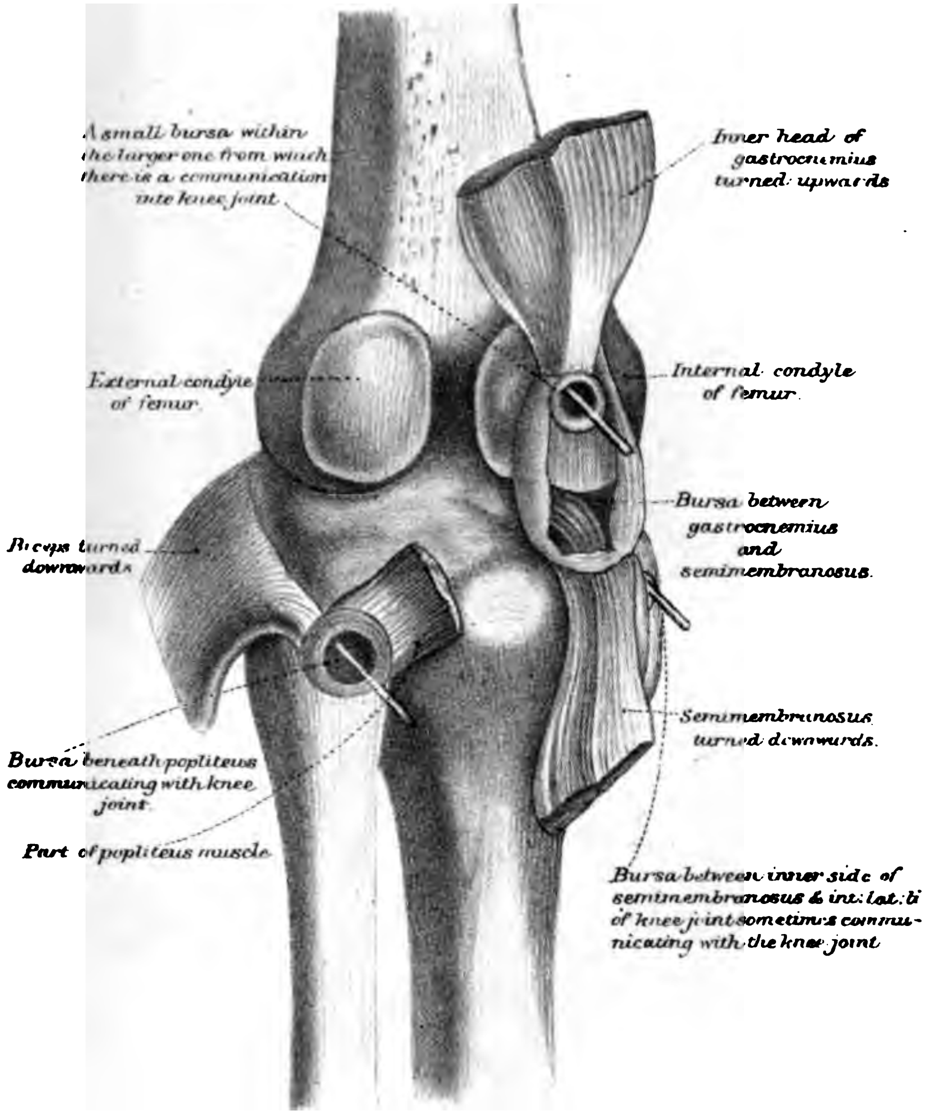
BURSÆ IN CONNECTION WITH THE FRONT OF THE KNEE.


Femur.
Bursa between the Quadriceps extensor tendon & the thigh.
Aperture leading from bursa into joint.
Patella.
Ligament joining patella to tibia cut acros
Bursa between ligamentum patellæ & top of tibia.
Sartorius
Gracilis
Semitendinosus
Bursa between the inner hamstrings & the inner side of the head of the tibia.
Fibula
Tibia

A. Henman del. after Monro

West, Newman & Co Lith.

BURSÆ AT THE BACK OF THE KNEE.


A small bursa within the larger one from which there is a communication into knee joint
Inner head of gastrocnemius turned upwards
External condyle of femur
Internal condyle of femur.
Bursa between gastrocnemius and semimembranosus.
Biceps turned downwards
Semimembranosus turned downwards.
Bursa beneath popliteus communicating with knee joint
Part of popliteus muscle
Bursa between inner side of semimembranosus & int: lat: li of knee joint sometimes commu-nicating with the knee joint

A. Hensman del. after Monro
West, Newman & Co. Lith.

the inner tuberosity of the tibia. It sometimes communicates with the preceding bursa, and rarely with the synovial cavity of the joint.

Along the outer border of the space there generally exist four bursæ—one between the tendon of the popliteus muscle and the external lateral ligament of the knee-joint, which does not, as a rule, communicate with the synovial cavity; another, situated obliquely beneath the tendon of the popliteus, and separating it from the external tuberosity of the tibia. This is in reality only a diverticulum of the synovial sheath, and frequently communicates with the cavity of the superior tibio-fibular joint. A third, which separates the tendon of the biceps from the external lateral ligament of the joint, is situated immediately above the head of the fibula, and has the external popliteal nerve running along it. A fourth small bursa is sometimes found beneath the tendon of the external head of the gastrocnemius; it is sometimes only a prolongation of the bursa between the popliteus and the external lateral ligament. Neither of these last two are by any means constant.

Any of these popliteal bursæ may become enlarged, and then might possibly be mistaken for a popliteal aneurism. I have described such a case in a paper in the *Medical Times and Gazette* of November 6th, 1875.

THE MUSCLES WHICH PASS OVER AND MOVE THE KNEE-JOINT are attached, some of them to the pelvis, and move the hip as well as the knee; others, to the femur above and the tibia below, and move only the knee; while others again arising from the femur are inserted into one of the bones of the foot, and move both the knee and the ankle.

The *extensors of the knee* are five in number, viz., the rectus, vastus externus and internus, crureus, and tensor vaginæ femoris. All pass over the front of the joint except the last. The prolongation of the fascial insertion of the tensor vaginæ passes over the outer and fore part of the joint. Of the four muscles which unite in the common extensor tendon one only arises from the pelvis, viz., the rectus femoris. This muscle, besides assisting to extend the knee, also helps to flex the thigh on the abdomen. It acts unequally from its two heads of origin according as the thigh is extended or flexed; in the former position the head which arises from the inferior iliac spine is in action, in the latter the acetabular head is alone tense. The other three muscles which unite in the common tendon, viz., the two vasti and the crureus, take origin from the femur, and their action is confined to the knee-joint. That these powerful muscles are not required to be in action for the purpose of keeping the body in the erect posture, is proved by the freedom with which the patella floats between the finger and thumb when a person is standing with his feet flat on the ground, and also by the suddenness with which the limb drops, if in this position a slight blow be struck against the hamstring tendons.

The *subcrureus* extends from the lower part of the front of the femur, and is inserted into the upper and anterior part of the capsule of the knee-joint. Its action is to raise the capsule in extension of the joint, and so to prevent the pinching of the synovial membrane which might otherwise occur.

The *tensor vaginæ femoris*, which arises from the crest and anterior notch of the ilium, is inserted into the fascia of the thigh below the great trochanter; this part of the fascia lata is prolonged into a strong tendinous band, which is fixed below into the ridge which extends from the tubercle to the outer tuberosity of the tibia. Besides making tense the fascia and assisting to rotate the thigh inwards, it acts also as an extensor of the knee.

The *flexors* are eight in number, viz., the three hamstring muscles (biceps, semi-membranosus, and semi-tendinosus), the sartorius, gracilis, popliteus, gastrocnemius, and plantaris.

The sartorius and gracilis are on the inner side of the joint, the sartorius being above and in front of the latter. The semi-membranosus, semi-tendinosus, and inner head of the gastrocnemius pass over the back of the joint on the inner side; the semi-membranosus being further from, and the inner head of the gastrocnemius nearest to, the median line, while the thin tendon of the semi-tendinosus is superficial to the more bulky semi-membranosus. The biceps, outer head of the gastrocnemius, and plantaris lie along the outer side of the back of the knee, in the order named, from without inwards. The plantaris is slightly higher as well as nearer the median line than the head of the gastrocnemius.

Lastly, the tendon of the popliteus lies deeply below, and then beneath the outer head of the gastrocnemius, and spreads out as it inclines downwards and inwards from the outer side of the external condyle of the femur.

Of these eight muscles two alone, or, more strictly speaking, one and part of another, pass over the knee-joint only. These are the popliteus, and the short head of the biceps. Five (viz., the three hamstrings, the sartorius, and gracilis) arising from the pelvis, are inserted close below the knee, and passing over the hip as well as the knee, act on both joints; while two, viz., the gastrocnemius and the plantaris, arising close above the knee, are inserted by means of the tendo-Achillis into the os calcis, and thus act on the knee and ankle-joints.

The hamstrings flex the knee as well as extend the thigh. The biceps besides is an external rotator of the leg on the femur. The semi-membranosus and semi-tendinosus are inward rotators of the leg on the femur.

The popliteus is a direct flexor of the leg upon the thigh, while it also rotates the leg inwards when it is flexed as well as in the act of flexing. It is only during the state of flexion that its tendon lies in the groove on the femur.

The gastrocnemius and plantaris flex the knee when their action on the ankle-joint (which they extend) is either prevented or completed.

The sartorius and gracilis, besides acting to rotate inwards and flex the knee, also incline the leg inwards. The sartorius acts on the thigh as a flexor, while the gracilis is an adductor of the hip-joint.

Rotators of the Leg on the Thigh.—As has been described above, the biceps rotates the leg outwards, and the semi-membranosus, semi-tendinosus, sartorius, gracilis, and popliteus rotate it inwards.

MOVEMENTS OF THE KNEE-JOINT.—The purposes of the different parts of this joint, viz., the lateral and crucial ligaments, the fibro-cartilages, and the patella, have been already stated in the description of the several structures themselves. It remains now to give some general account of the various movements which occur at the knee. These are flexion and extension, with some slight amount of pronation and supination in the bent position. These movements are, however, by no means so simple as the corresponding movements at the elbow; for the knee, as has already been stated, is not a simple hinge-joint; and the pronation and supination instead of occurring between the tibia and fibula, as between the radius and ulna, is a movement of the tibia with the fibula upon the condyles of the femur.

The knee differs from a true hinge, such as the elbow and ankle, in the following particulars:—(1) Neither the whole nor any single individual part of the articular surface of one of the bones entering into the joint, remains applied against anyone portion of the other in every position of flexion and extension. Thus, in the flexed position, the hinder part of the articular surface of the tibia is in contact with the rounded back part of the condyles; in the semiflexed position, the middle part of the tibial facets are in contact with the *anterior rounded* part of the condyles; while in the fully extended position the anterior and middle part of the tibial facets are in contact with the flattened anterior surface of the condyles. So with the patella: one portion of the bone is in contact with one part of the trochlear surface of the femur in flexion, another with a different part of the same surface in mid-flexion, and a third with a third part of the femur in extension. In the elbow-joint, on the contrary, the whole of the sigmoid cavity of the ulna, including the articular surface of the olecranon, remains in contact with the end of the humerus in every position of the joint; so does the articular arch formed by the lower ends of the tibia and fibula remain in contact, in all states of the joint, with the surfaces of the astragalus.

This difference may be called *the shifting of the points of contact of the articular surfaces;* and to effect this alteration of points of contact in the case of the tibia and femur, there must be *a rotation of the tibia upon a transverse axis drawn through its own head,* besides the revolution of the bone round a transverse axis through the condyloid end of the femur.

2. The knee differs further from a simple hinge-joint in this also, that in passing from a state of extension into one of flexion, the tibia does not revolve round a *single* transverse axis drawn through the lower end of the femur between the points of attachment of the lateral ligaments, as the ulna does round the lower end of the humerus. On the contrary, the articular surface of the tibia *slides* forwards in extension and backwards in flexion, so that the axis round which it revolves upon the femur is a shifting one. This is seen by reference

to Diagrams IX., XI., and XII., by which it will be understood that, in extending the joint, the axis through the femur upon which the tibia revolves travels forwards as the tibia slides forwards beneath the condyles, and that in flexion it travels back again along the same line as the tibia slides back into its former position. This difference may be called the *shifting of the transverse axis through the femur.*

DIAGRAM IX.

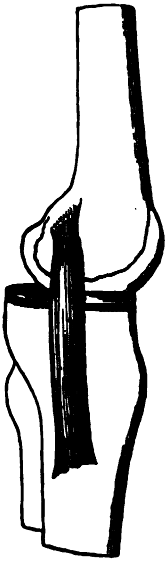
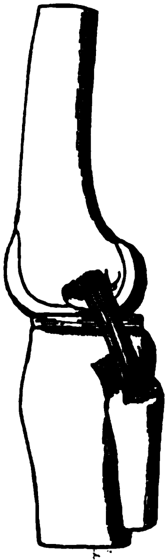


DIAGRAM X.



3. Another point of difference between the flexion and extension movements of the knee and of true hinge-joints is, that in the knee extension is accompanied by rotation outwards, and flexion by rotation inwards of the tibia upon the femur. This rotation occurs round a vertical axis, drawn through the middle of the outer condyle of the femur, and of the outer tuberosity of the tibia, and is most marked at the termination of extension and at the commencement of flexion. It is not quite the same movement as that which is described as pronation and supination. This rotation of the leg at the knee differs from the obliquity of the flexion and extension movements at the elbow, whereby the forearm comes inwards, *i.e.*, towards the trunk during flexion, and goes outwards during extension. At the knee the movement is a true rotation round

a vertical axis, running through the tibia and femur; at the elbow it is the inclination given to one bone by its following closely and continuously around the oblique surface of the other, *i.e.*, at the elbow the axis of movement is oblique instead of transverse.

4. The antero-posterior spiral curve of the femoral condyles is such that the interior part is a curve of a far greater circle than the posterior, and as a result of this arrangement certain ligaments which are tightened when the knee is extended and the column of the limb is rigid have their ends approximated, and are therefore slackened in flexion.

DIAGRAM XI.

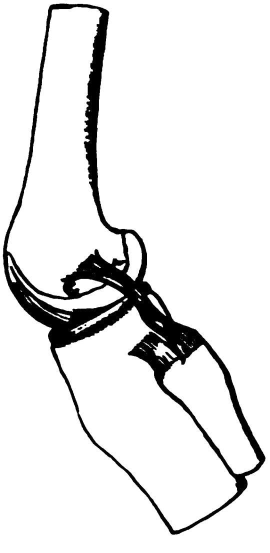
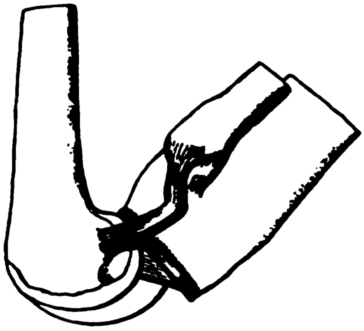


DIAGRAM XII.



Besides the rotation round a vertical axis, which is one of the accompanying movements of slight flexion and nearly completed extension at the knee-joint, there is a much more free rotation, also round a vertical axis, when the joint is flexed. This is *pronation* and *supination* of the knee. It begins to be possible when the knee is bent at an angle between 150° and 155°, and becomes freer and freer as the joint is bent more and more. The axis of rotation passes through the inner tubercle of the spine of the tibia, so that the outer tuberosity moves in the arc of a larger circle than does the inner, and therefore is required to move more easily and freely; to this end the shape of its articular facet and the loose connexion of the external semilunar cartilage with it are adapted. The Webers have described this rotation in the horizontal plane of the joint as being like the rotation of the front wheels of a carriage in passing round a corner; the inner condyle of the femur being the representative of the nearly fixed wheel, and the outer the representative of the wheel which describes the curve. The ligaments are relaxed in flexion sufficiently to allow of a rotation of 36°.

In *extension* all the ligaments are on the stretch, with the exception of the ligamentum patellæ and the front of the capsule. These are so loose that the patella can be easily moved from side to side while we stand upright. Extension is checked both by the anterior and posterior crucial, as well as by the lateral ligaments.

In *flexion* the ligamentum patellæ and the anterior portion of the capsule are on stretch, so also is the posterior crucial ligament in extreme flexion, though it is not quite tight in the semiflexed state of the joint. All the other ligaments are relaxed, although the relaxation of the anterior crucial ligament in extreme flexion is but slight. Flexion is only checked during life by the contact of the soft parts in the ham; the angle of extreme flexion in the knee of the author, when lying on his back with the thigh bent up so that the foot rested flat upon the couch, was 38°, as measured (by Hawksley) with an angle measurer with a circle of nine-inch diameter. *During partial flexion*, when rotation, *i.e.*, *pronation* and *supination*, are possible, both the crucial ligaments are somewhat relaxed; so are the lateral ligaments, and the ligamentum patellæ is not upon the stretch.

Pronation is limited by the external crucial ligament; both lateral ligaments are loose.

Supination is limited by the internal and external lateral ligaments; the crucial ligaments have no controlling effect upon it, as they become untwisted by it. The direction of the lateral ligaments which slope, the outer backwards to the fibula, the inner forwards on the tibia, gives them control over supination and outward rotation.

Rotation, as distinguished from pronation and supination, is checked by the lateral ligaments, which in the nearly extended position are tense.

Sliding movements are checked by the crucial and lateral ligaments; sliding forwards especially by the anterior, sliding backwards by the posterior crucial.

CHAPTER XVIII.

TIBIO-FIBULAR OR PERONEO-TIBIAL JOINTS.

Class, Diarthrosis. *Subdivision*, Arthrodia.

THE fibula is connected to the tibia throughout its whole length; at its upper and lower extremities by means of synovial joints, and along the shaft by means of an interosseous membrane. The superior articulation has usually a complete synovial sac of its own; while that of the inferior articulation is a prolongation of the synovial sac of the ankle-joint. Very little movement is permitted between the bones.

The Superior Tibio-fibular Articulation.

The superior tibio-fibular articulation is about a quarter of an inch below, and quite distinct from the knee-joint at its upper and anterior part; but at the posterior superior aspect, where the border of the outer tuberosity of the tibia is bevelled by the popliteus muscle, it is in the closest proximity to the bursa beneath its tendon, and is separated from this prolongation of the synovial sac of the knee by only a very thin septum of areolar tissue.

Binding together the upper ends of the tibia and fibula there is a thin capsular ligament, strengthened in front and behind by short strong ligamentous fibres, above by the tendon of the biceps muscle, and below by a quantity of interosseous tissue. The external lateral ligament by both its parts also assists in keeping the fibula fixed against the tibia.

THE BONES—*Tibia.*—At the posterior and outer part of the external tuberosity of the tibia is a nearly flat and oval-shaped facet, the size of a fourpenny-piece. It is very slightly concave from above downwards, and its longest axis is from before backwards. It is obliquely inclined, so that although its upper margin forms part of the vertical border of the tuberosity, it is situated on the under aspect of the overhanging bone, and looks downwards, outwards, and slightly backwards.

Curving forwards from its anterior margin is an arched ridge to which, and to the bone below it, the tendon of the biceps is attached; curving forwards also from its lower margin is another and fainter ridge which joins the above, about halfway between the facet and the tubercle, and marks the line of the epiphysis. An interval of a quarter of an inch or more separates it from the facet for the outer condyle of the femur, and to the bone between are attached part of the capsular ligament of the knee and of the outer coronary ligament, and also part of the capsule of the upper tibio-fibular joint. Above it posteriorly, the bone is grooved for the tendon of the popliteus muscle. Below it, the tuberosity curves sharply inwards to the shaft, and to the bone here the superior interosseous ligament is attached.

The Fibula.—The head of the fibula is an irregularly rounded mass about the size of a small walnut. Projecting above the rest on its outer part is a little eminence, the styloid process of fibula, to which the short external lateral ligament is attached. Below and to the inner side of the styloid process is an oval-shaped articular facet, which looks chiefly upwards, but is also inclined inwards and a little forwards. This facet is about the same size as the facet on the tibia, and like it is longer from before backwards than from above downwards. It is slightly concave from before backwards. It does not occupy the whole of the upper surface of the head of the fibula, for in front of it there is a rough groove to which part of the biceps tendon is attached. On the upper and fore part of the head is a rough surface sloping forwards and downwards from the styloid process, to which the front part of the tendon of the biceps and the long external lateral ligament are attached. Further inwards than this, but still on the anterior surface, the anterior tibio-fibular ligament is attached. On the outer side of the head and running vertically downwards from the styloid process is a ridge, in front of which the hinder portion of the tendon of the biceps is attached; behind the ridge the outer surface of the bone is subcutaneous. On the posterior surface is a ridge running obliquely downwards and inwards from the back of the styloid process, which meets another ridge running downwards and inwards from the anterior surface. Above the ridge the posterior tibio-fibular ligament is attached, and the tendon of the popliteus passes; and below it is a depression continuous with the back of the shaft, from which arises the soleus muscle. Where these two ridges meet on the inner side of the head there is often quite a prominent tubercle, from half to three-quarters of an inch below the articular facet, to which and to the bone above, the superior interosseous ligament is attached.

THE LIGAMENTS—*Capsular Ligament.*—Surrounding the articular facets of the tibia and fibula is a well-marked fibro-areolar capsule. This capsule is attached close to the margin of the facet of the tibia all around, and close to the facet of the fibula above and in front, but at a short distance from its margin behind and below. Between the tendon of the biceps and the front border of the tendon of the popliteus, as it inclines downwards above the head of the fibula, this articulation is separated from the knee-joint by its own capsule, as well as by the capsule and part of the outer coronary ligament of the knee; but lower down behind, the capsule of this joint is often very thin, and sometimes communicates with the popliteal bursa.

Anterior Tibio-fibular Ligament.—Thickening the capsular ligament in front are a few fibres, the anterior tibio-fibular ligament, which pass upwards and inwards between the adjacent surfaces of the bones below the anterior portion of the tendon of the biceps.

Posterior Tibio-fibular Ligament.—A few fibres also thicken the capsule on the posterior aspect below the bursa of the popliteus. These pass from the lower and posterior side of the head of the fibula upwards and inwards to the adjacent part of the tibia. They are not so well-marked as the anterior ligament.

Superior Interosseous Ligament.—A quantity of dense yellow fibro-areolar tissue binds together the opposite surfaces of the tibia and fibula below the articular facets on the bones for about three-quarters of an inch. It is continuous along the tibia with the interosseous membrane uniting the shafts of the bone.

The *biceps tendon* is divided by the long external lateral ligament, with which, at its insertion into the head of the fibula, it is inseparably blended. The part behind the ligament is inserted into the outer surface of the head of the fibula in front of the base of its styloid process. The part in front of the ligament is much the larger, and has an attachment to the ridge on the border of the outer tuberosity of the tibia, as well as to the front surface of the head of the fibula; moreover, there is a reflection of some of the posterior fibres which are passing towards the tibia backwards and outwards, to be attached to the hollow in front of the styloid process of the fibula.

The insertion of the tendon of the biceps is indeed the chief bond of union between the tibia and fibula, and holds the bones strongly together in front and above, after all other connexions have been severed.

The SYNOVIAL MEMBRANE, which lines the joint, sometimes, *i.e.*, in about one joint out of every four, communicates with the bursa beneath the popliteus. It never communicates with the knee-joint excepting through the medium of this bursa.

The ARTERIES which supply the joint are some of those to the knee-jcint, viz., the superior external articular branch of the popliteal, and the recurrent branch af the anterior tibial. Moreover, a branch which runs beneath the popliteus sends a small filament into the back of the joint.

The NERVES are the inferior articular branch of the external popliteal, and the recurrent branch which springs from the point of bifurcation of the trunk of the external popliteal.

The BURSÆ are three in number, viz., those in connexion with the tendons of the popliteus and biceps, described under the bursæ of the knee-joint. That beneath the tendon of the popliteus is of the greatest importance, as it frequently communicates with the superior tibio-fibular joint, and on this account the head of the fibula should not be removed, as is sometimes recommended, in amputation of the leg below the knee-joint.

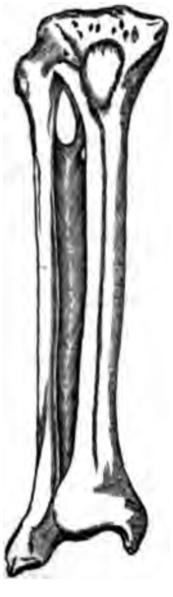
THE MUSCLES.—Only two muscles pass over the articulation, which have a close relation to it, viz., the tendons of the biceps and popliteus. The popliteus grooves the back part of the outer tuberosity, and passes over the back of the joint. The fascial prolongation of the tensor vaginæ femoris passes down in front of it, and the outer head of the gastrocnemius and the plantaris pass over it behind. None of these produce any appreciable movement in the joint, though doubtless a slight gliding movement of the fibula on the tibia is produced by the pull of the biceps and the contraction of the popliteus; upwards and backwards by the biceps, and forwards by the popliteus. It must, however, be remembered that the biceps is inserted into the tibia as well as into the fibula, and holds the bones together; and that the popliteus has no direct attachment to the fibula whatever (being connected with it only through some of the ligamentous structures of the knee-joint which surround the tendon), and therefore its tendon can only act on the joint like a strap.

MOVEMENTS.—This joint is constructed in such a way as to allow of the fibula giving some support to the tibia in transmitting weight to the foot, but so as to allow of none but the slightest movement between the bones. The articular facet of the tibia overhangs and is received upon the articular facet of the head of the fibula in a plane between the vertical and transverse.

Only gliding movements can be effected at this joint; these are produced by the variations in the state of the muscles which arise from the two bones and by the traction of the biceps and compression of the popliteus. The purpose of the synovial joint is more to prevent friction than to effect change of position of the bones.

The Tibio-fibular Interosseous Membrane.

DIAGRAM XIII.



In the interval between the upper extremity of the shaft of the bones and the inferior tibio-fibular joint an interosseous membrane is stretched. It is attached all along the outer border of the tibia, and to the ridge on the fibula which divides the inner surface of the shaft into an anterior and posterior portion. It is deficient above over an area of an inch or more—measured from the under aspect of the superior tibio-fibular joint. This aperture is bounded above and on the inner side by the free edge of the membrane which is attached to the outer border of the tibia, as this curves upwards beneath the outer tuberosity to the facet for the fibula; on the outer side by the fibula itself; and below by a lunated margin formed by closely packed fibres which curve downwards and outwards from tibia to fibula with their concavity looking towards the opening. The membrane consists of a thin aponeurotic and translucent lamina (which in the dry state looks exactly like a portion of a pig's bladder dried and distended) of oblique fine fibres, some of which are running from tibia to fibula, others from fibula to tibia, but all inclined downwards. They are best marked near their attachment to the bones, and they are stronger and denser below as they gradually approach the inferior interosseous membrane with which they are continuous. It is usually stated that there is an opening at the lower part of this membrane for the passage of the anterior peroneal vessels, and also that it is perforated in several places for the passages of small vessels. This undoubtedly is often the case, but in two carefully prepared specimens now lying before me, there is no perforation whatever appreciable to the naked eye excepting the large one at the top, and a minute foramen a little below it, and close to the tibia in one of them.

This interosseous membrane can scarcely be said to add to the security of the union of the tibia and fibula, nor to be of use in transmitting weight as is the corresponding membrane of the forearm. Its chief, if not only use, is to afford a surface for the origin of muscles, and to act as an inter-muscular septum between the muscles on the front and back of the leg.

The inferior interosseous ligament, which will be described with the inferior tibio-fibular joint, undoubtedly forms a firm bond of union as well as a padding between the bones, and serves the purpose of connecting cartilage. It has to bear in great part the strain in walking and running, when the weight of the body falls obliquely upon the foot, and indeed of every force which has a tendency to separate the tibia from the fibula.

The muscles in relation with the interosseous membrane are: in front—

The *tibialis anticus*, which arises from the upper two-thirds of its tibial border.

The *extensor longus pollicis*, arising from the middle half of its fibular border.

The *extensor longus digitorum*, which arises from the fibular border above the origin of the extensor pollicis.

The *peroneus tertius*, arising from the lower fourth of the membrane.

Behind—

The *tibialis posticus* arises from the whole of the membrane except for an inch or more at its lowest part, from which the *flexor longus pollicis* arises.

Inferior Tibio-fibular, or Peroneo-tibial Articulation.

As in the upper joint, so here, the two bones are united by ligaments which form a capsule which is lubricated by a synovial membrane. Here, however, this membrane is prolonged from the ankle-joint, and the cartilage-covered facets are much smaller than in the upper joint.

TIBIA.—On the outer surface of the lower extremity and contiguous part of the shaft is an elongated triangular depression, limited in front by the prominent interosseous ridge, and behind by the posterior branch which runs downwards from the ridge for about two inches to the posterior external angle of the lower extremity. This depression is very rough, and gives attachment throughout the greater part of its extent to the inferior interosseous ligament. It is about two inches in height, with its base along the outer margin of the facet for the astragalus. It is concave from before backwards. At the base in front there is a minute triangular or crescentic facet tipped with cartilage in the recent state, with which the fibula articulates by a corresponding cartilage-coated facet.

FIBULA.—On the inner surface of the lower end of the shaft of the fibula is a rough, somewhat raised, elongated, triangular surface, the base of which is formed by the minute articular facet prolonged upwards from the malleolus. This rough surface is limited in front and behind by the ridges into which the inner border of the fibula bifurcates below. It gives attachment to the inferior interosseous ligament, except for about three-eighths of an inch below. The fibula is in actual contact with the tibia only by its articular (cartilage-coated) surface, which is minute in size, crescentic in shape, and continuous with the articular facet of the malleolus. Prolonged upwards between the bones beyond the articular facets, as high as the lower part of the inferior interosseous ligament, is the synovial membrane of the ankle-joint.

LIGAMENTS.—The *anterior peroneo-tibial ligament* is three-quarters of an inch in width, and extends obliquely downwards and outwards. To the tibia it is attached at the external and anterior angle of its lower extremity, close to the margin of the facet for the astragalus. To the fibula it is attached along the lowest half-inch of the ridge in front of the superficial triangular surface of the bone, and to the anterior surface of the malleolus, nearly down to the anterior portion of the external lateral ligament of the ankle. The fibres of this ligament increase in length from above downwards, the lowermost being over an inch in length. To it a part of the anterior ligament of the ankle is fixed.

The *posterior peroneo-tibial ligament* is very similar to the anterior in form, size, direction, and attachment. It extends from the external angle of the posterior surface of the lower end of the tibia, downwards and outwards to the fibula, along the lowest half-inch of the ridge separating the posterior from the external surfaces, and to the upper half of the posterior border of the external malleolus.

The *transverse ligament,* a strong rounded band, extends between the extremity of the tibia and the posterior and inner angle of the base of the external malleolus. It is best seen after dividing the posterior peroneo-tibial ligament. It is attached at one end to nearly the whole of the posterior margin of the large quadrilateral articular surface of the tibia, but more especially to its outer half, just above the horizontal groove near the margin. It then inclines a little forwards, and is attached to the fibula above the rough fossa behind the articular surface of the malleolus as well as slightly into the fossa.

The *inferior interosseous ligament* is a dense mass of short fibres, passing transversely between the apposed lower ends of the tibia and fibula, except for three-eighths of an inch at the extremity of these surfaces, where there is a synovial cavity.

This ligament extends from the anterior to the posterior peroneo-tibial ligaments. In front, it reaches upwards for an inch and a half, but behind, only about half this height. On separating the bones, the ligament is seen on section to be a felt-like membranous structure.

SYNOVIAL MEMBRANE.—The *synovial cavity* of this articulation communicates with that of the ankle-joint, through a narrow chink between the articular surfaces of the external malleolus and the extremity of the tibia. It is semilunar in shape, with its convexity upwards, where it is limited by the lower end of the inferior interosseous ligament. It is wider in front, where it measures three-eighths of an inch in depth, than behind.

Well-marked articular cartilage covers only a small triangular portion of each bone at this joint, viz., its lower anterior extremity, and sometimes a narrow strip of bone behind this. The cartilage is continuous with the articular cartilage on the ankle-joint surfaces of the bones; but elsewhere the bony surfaces of this joint are rough, and coated by a loose periosteum, over which the synovial membrane extends. Where the cartilage is deficient the bones are not in actual contact with one another, and thereby provision is made for the slight lateral yielding of the arch of the ankle.

NERVES.—This joint being as it were an offset of the ankle-joint, gets its nerve supply from some of the same sources as the ankle.

ARTERIES.—Some of the arteries of the ankle-joint supply this joint also. The *anterior peroneal* passes over it in front; and the *posterior peroneal* pierces the posterior ligament of the ankle-joint close to it, behind. Sometimes a branch from the *anterior tibial*, or its external malleolar *offset*, enters it.

BURSÆ.—There are none having any special relation with this joint, as distinct from the ankle-joint.

MUSCLES.—The peronei muscles pass over the fibula, but the bones are not moved upon one another by muscular action, excepting so far as they yield to allow of the play of the astragalus.

MOVEMENTS.—The anterior ligament is always tight, the posterior and transverse permit of slight yielding of the bones in extreme flexion. All are concerned in bracing the bones very firmly together, so as to strengthen the arch of the ankle-joint.

The advantage of an arch so formed over a simple bony one is obvious: an amount of elasticity is provided, whereby slight expansion is allowed during extreme flexion of the foot on the leg. By this movement the broader part of the astragalus is pressed under the arch; but perfect contact of the malleoli with the sides of the astragalus is still maintained on again bringing the foot to a right angle with, or extending it upon, the leg

CHAPTER XIX.

THE ANKLE-JOINT.

Class, Diarthrosis. *Subdivision*, Ginglymus.

THE ankle-joint, or the union of the leg with the foot, is a perfect ginglymus or hinge-joint. It is to the form of the bones, and to their exact adaptation to one another, that its great security and strength are owing.

It has been, though not quite correctly, compared to the tenon and mortise-joint used by mechanics, from which, however, it differs in some respects.

An account of the bones, no less than of the ligaments entering into its formation, is essential to a correct understanding of its use and mechanism.

The bones of the joint are three: the tibia and fibula, by their lower extremities; and the astragalus, by its upper and two lateral surfaces. The tibia and fibula take very unequal shares in its construction, for whereas the latter, by the inner surface of its malleolus, articulates only with the outer side of the astragalus; the former, by the broad quadrilateral surface at the extremity of the shaft, and by the outer surface of the inner malleolus, articulates with the upper and inner surfaces of the bone.

An irregular archway is thus formed by the two bones of the leg, under which is received the astragalus; the outer buttress, which is the longer, being formed by the fibula, while the inner buttress and the span of the arch are formed by the tibia. These two bones are firmly bound together by means of the ligaments which have been described with the inferior tibio-fibular articulation. So strong is this union that it is much more frequent, as a result of accidents, for the archway to be injured by fracture through one or other of the bones, than by a laceration of these ligaments, and the consequent separation of the bones from one another.

THE FIBULA.—Only its malleolus enters into the ankle-joint. This portion of the bone presents two surfaces; an internal, looking towards the astragalus; and an external, forming the outer prominence of the ankle; and two borders, an anterior and posterior. The *internal surface* is partly articular and partly non-articular. The articular part is a more or less triangular facet, with its apex downwards and forwards; it is convex from above downwards, and slightly concave from before backwards; the base extends across the whole width of the surface, is somewhat curved downwards behind, and is separated by a groove from the shaft of the bone; the posterior border of the facet slopes forwards from base to apex,and behind it is the non-articular portion of the inner surface, which is hollowed out into a deep rough fossa, wider but shallower below than above. This fossa is limited behind by the posterior border of the malleolus; it affords room for a little adipose tissue, and its margins give attachment to two ligaments, viz., below and behind, to the posterior portion of the external lateral ligament, and above to the transverse ligament of the inferior tibio-fibular articulation.

The *external* surface is divided into two unequal parts by the posterior of the two ridges, into which the anterior crest of the shaft bifurcates, and by which the triangular subcutaneous surface at the lower end of the fibula is bounded. The inferior extremity of this ridge forms the apex of the malleolus, the ridge itself can easily be traced on the living body, immediately in front of the peronei tendons; it is most prominent below, and provides a surface round which the peronei tendons play as they pass the point of the outer ankle. The part of this surface which is behind the ridge is much the smaller, and forms an elongated groove, which lodges the tendons of the peroneus longus and brevis muscles; there is sometimes a slight tubercle in the lower part of the groove.

The *anterior border* is very thick for the attachment of ligaments, is continuous above with the anterior of the two ridges, into which the anterior crest bifurcates, and becomes less thick as it slopes backwards to the lowest point or apex of the malleolus.

The *posterior border* is much thinner than the anterior; it is continuous above with the posterior crest of the shaft, and inclines forwards below to the apex of the malleolus; it separates the groove for the peronei tendons from the fossa on the inner surface.

THE TIBIA.—The lower articular extremity of this bone is of a quadrangular form, prolonged downwards at the inner border into the inner malleolus. It presents for examination a quadrilateral facet with its four borders, and the malleolus. The *quadrilateral surface* is a smooth facet at the extreme end of the tibia, concave from before backwards, convex from side to side; it has a broad ridge running from before backwards about midway between the lateral borders. The transverse measurement of this facet increases gradually from behind forwards, partly by the bevelling off of the malleolus in front, and partly on account of the greater thickness of the forepart of the lower end of the bone. The antero-posterior measurement increases gradually from the inner to the outer border.

The anterior margin of this facet is sharply defined. Above it is a well-marked horizontal groove, and above this again is a prominent crest of bone somewhat overhanging the groove. The posterior margin is narrower, but projects further downwards than the anterior. Above it is a horizontal groove, and near its fibular side is a faint oblique groove for the flexor longus pollicis tendon. The external margin is concave for the reception of the lower end of the fibula; the anterior horn of this concavity is more prominent than the posterior, and the articular surface is prolonged around it a little way so as to be continuous with the inferior tibio-fibular articulation. Projecting downwards from the inner border is the internal malleolus of the ankle. The line of union of the shaft with the lower epiphysis corresponds in front and behind with the ridge above the groove on each aspect. The epiphysis includes the whole of the malleolus on the inner side, and the portion of bone with which the fibula articulates on the outer side.

The *malleolus* has four surfaces. The inner surface is rough and subcutaneous, and is continuous above with the inner aspect of the shaft. The posterior surface is obliquely grooved for the tendons of the tibialis posticus and flexor longus digitorum; it is separated from the inner surface by a sharp ridge running downwards and forwards to the lower border. The anterior surface is rough and grooved. The outer surface is a smooth facet and the outer surface is a smooth facet continuous with the horizontal facet, to articulate with the inner smooth surface of the astragalus. At its base it is of the same width as the inner border of the quadrilateral facet, but is bevelled inwards in front. At its lower part it is very narrow, being a prolongation from only the anterior portion of the base.

The posterior border of its articular or outer surface is very short, is continuous with the posterior border of the horizontal facet, and separates the posterior from the outer surfaces of the malleolus. The lower border is irregular, being notched behind and prolonged downwards into a broad tongue in front. The anterior border is quite vertical, continuous above with the anterior margin of the quadrilateral facet, and separates the outer from the anterior surface of the malleolus.

THE ASTRAGALUS.—The whole of the upper, outer, and inner surfaces, and the greater part of the posterior surface of the astragalus, assist in forming the ankle-joint, either by smooth cartilaginous facets for articulating with the bones of the leg, or by rough surfaces for the attachment of ligaments. There are three facets, which are continuous one with the other. The *superior* occupies the posterior two-thirds of the upper surface of the bone; it is arched considerably, having its convexity upwards and from before backwards; it is concave from side to side, in adaptation to the antero-posterior ridge on the quadrilateral surface of the tibia. It is decidedly narrower behind than in front, longer on the inner side than the outer; its outer margin generally extends slightly further forward than the inner, and the inner border invariably further backwards than the outer.

The outer border is higher and more prominent, especially in front, than the inner, so that there is a slight inward obliquity given to this upward-looking facet. The outer border is much less rounded off as it passes into the facet on the outer surface of the bone than is the internal border as it curves over into the facet for the internal malleolus.

The anterior border is straight; the posterior is curved with its convexity backwards, and forms a lip overhanging a horizontal groove on the posterior surface of the bone, which extends into a rough fossa behind the outer articular facet.

The *external facet* is triangular in form, with its base, which corresponds to the entire outer border of the superior facet, above, and its apex below and in front; it is concave from above downwards, so that the lower part looks a little upwards, slightly convex from before backwards, and occupies all the outer surface of the astragalus, except an irregular-shaped rough depression below and behind, and the anterior inferior corner of this surface.

The *internal facet*, much smaller than the external, occupies less than half the inner surface of the astragalus. It is concave in both directions, is deeper in front than behind in adaptation to the inner malleolus, and its anterior extremity reaches further forwards than the anterior border of the superior facet. The lower border of this facet is sharply defined and crescentic in outline, below it the inner surface of the astragalus is rough and irregularly depressed.

The upper surface of the astragalus in front of the superior facet is rough and depressed into a well-marked fossa; it forms part of what is styled the neck of the bone. The posterior surface is very narrow from above downwards, it has a slight transverse groove, best marked at the outer corner; and a well-marked oblique groove, running downwards and inwards for the lodgment of the tendon of the flexor longus pollicis; except along these grooves, the posterior surfaces afford attachment for the posterior ligament and the posterior part of the external lateral ligament of the ankle.

THE LIGAMENTS.—These together form a complete capsule for the ankle-joint, and by being attached in places beyond the astragalus assist in forming the capsules of some of the tarsal joints. There are four named ligaments, viz., the anterior, the posterior, and the internal and external lateral ligaments.

The *anterior ligament* is a thin membranous structure, attached above to the front of the tibia and fibula from the internal to the external lateral ligaments. It is connected from within outwards to the middle of the anterior surface of the inner malleolus, to a depression between the malleolus and the quadrilateral facet of the tibia, to the crest of bone above the transverse groove, which is generally so well-marked along the anterior border of the lower end of the tibia; it is next blended with the anterior ligament of the inferior tibio-fibular joint, and still further out is attached to the anterior border of the external malleolus.

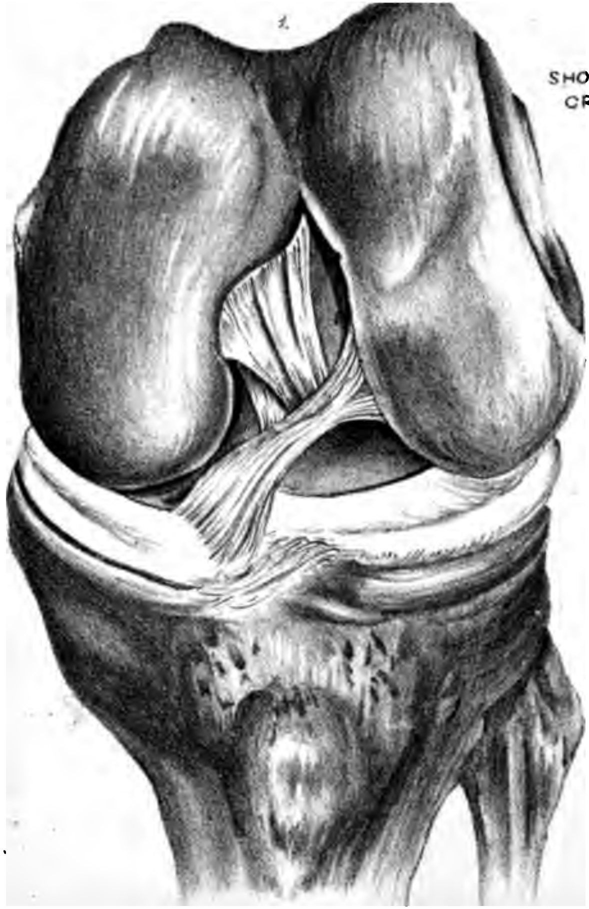
Below, it is connected with the rough anterior portion of the upper surface of the astragalus in front of the fossa. It is thus attached to the tibia above and to the astragalus below at some distance from their articular facets. On the inner side it is fixed inferiorly just in front of the facet for the inner malleolus, is continuous with the internal lateral ligament, and passes forwards to blend with the dorsal astragalo-scaphoid ligament. On the outer side it is attached to the astragalus just in front of and below the angle at which the external lateral joins the superior articular facet. It is here connected with the bones much closer to their facetted surfaces, and becomes blended with the anterior portion of the external lateral ligament. Except on the inner side of the foot the anterior ligament is extremely thin; a quantity of fat which rests on the neck of the astragalus and front of the tibia is covered in by it, and on attempting to clean this away the ligament is removed also.

The *posterior ligament* is a very thin membraniform structure connected above with the external malleolus internal to the peroneal groove, to the hinder part of the lower end of the tibia, external to the groove for the tibialis posticus tendon, and to the posterior tibio-fibular ligament; below it is attached to the posterior surface of the astragalus from the internal to the external lateral ligaments.

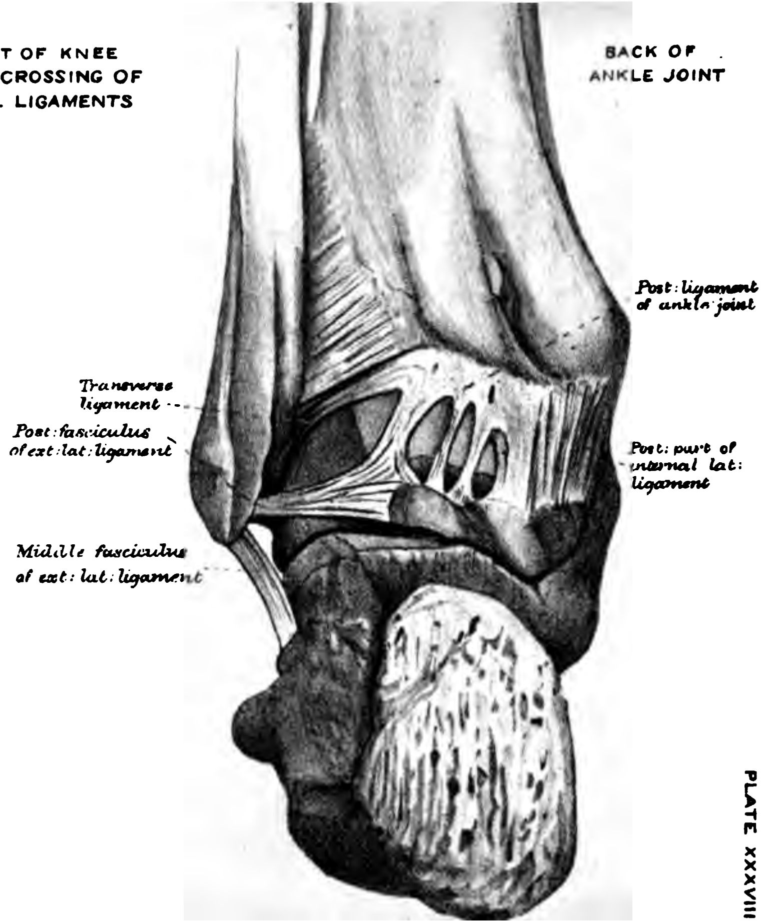
It is separated from the tendon of the flexor longus pollicis, which is superficial to it, by some fatty tissue, and it must be observed that the course of this tendon over the back of the joint serves the purpose of a much stronger posterior ligament.

The *internal lateral* or *deltoid ligament* is attached superiorly to the internal malleolus along the lower border, and to its anterior surface superficial to the anterior ligament, very strong fibres being fixed to the notch in the lower border of the malleolus. From this connexion it radiates, the posterior fibres are short, and incline a little backwards to be fixed to the rough inner surface of the astragalus, close to the superior articular facet, and into the tubercle to the inner side of the flexor longus pollicis groove. The fibres next in front are numerous and form a thick and strong mass, filling up the rough depression on the inner surface of the astragalus, whilst some pass over the calcaneo-astragaloid joint to the upper and inner border of the sustentaculum tali. The portion which is connected above with the anterior surface of the malleolus passes

PLATE XXXVIII



FRONT OF KNEE
SHOWING CROSSING OF
CRUCIAL LIGAMENTS


Transverse ligament
Post: fasciculus of ext: lat: ligament
Middle fasciculus of ext: lat: ligament
Post: ligament of ankle joint
Post: part of internal lat: ligament

BACK OF
ANKLE JOINT

downwards and somewhat forwards to be attached to the calcaneo-scaphoid ligament.

The *external lateral ligament* consists of three distinct slips. The *anterior* portion is ribbon-like, and is connected with the anterior border of the external malleolus just below the point of attachment of the anterior ligament of the ankle. Below, it is fixed to the astragalus in front of the facet for the fibula, *i.e.*, on the rough surface overhanging the sinus pedis. The *middle* portion is a strong roundish bundle, which extends obliquely downwards and somewhat backwards from the anterior border close to the attachment of the anterior portion of the ligament, and from the outer surface of the malleolus just in front of the apex, to a tubercle on the outer surface of the os calcis. The *posterior* portion is almost horizontal; it is a strong thick band, attached at one end to the border of the malleolus, which separates the peroneal groove from the fossa on the inner surface, and slightly to the lower part of the fossa itself; and at the other end to the rough outer surface of the astragalus below and behind the articular facet for the fibula, as well as into the tubercle to the outer side of the groove for the flexor longus pollicis tendon on the posterior surface of the astragalus. Often a slip curves upwards from this ligament, and becomes blended with the posterior ligament.

The SYNOVIAL MEMBRANE of the ankle is extensive; besides lining all the ligaments just described, it sends upwards a short cul-de-sac for the inferior joint between the tibia and fibula. This little sac is limited above by the strong interosseous ligament uniting the bones. Upon the anterior and posterior part of the ankle the synovial membrane is very loose, and extends beyond the limits of the articular facets as it lines the thin and delicate anterior and posterior ligaments of the joint. It is said to contain a greater quantity of synovia than any other joint in the body.

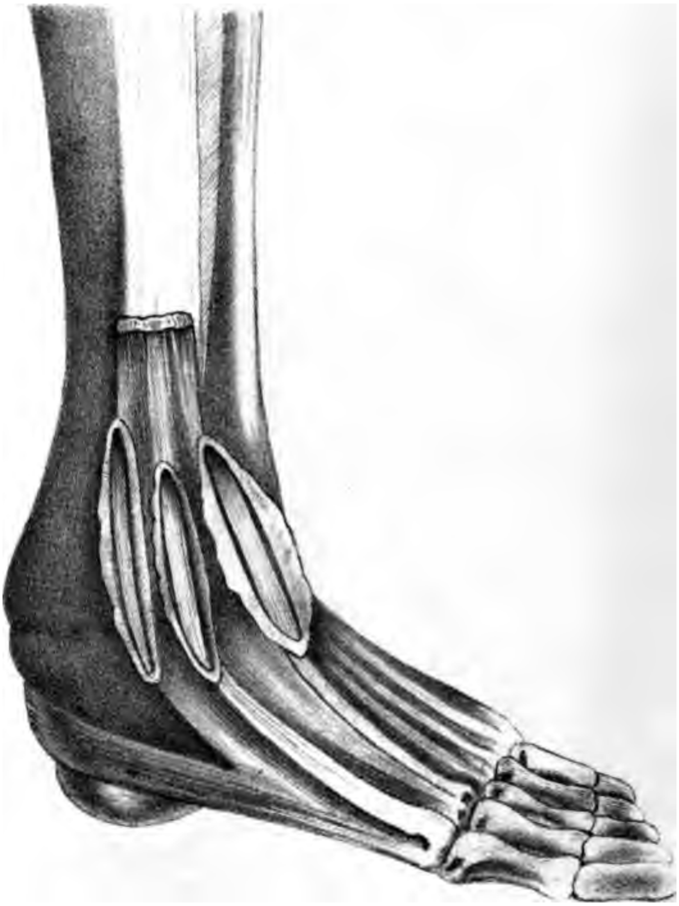
ARTERIES.—*From the anterior tibial artery* two or three fair-sized vessels arise between the external malleolar and tarsal branches of the same trunk, and enter the joint after ramifying on and in the anterior ligament. The *anterior peroneal*, as it passes down in front of the outer malleolus to join the external malleolar artery, sometimes supplies it, or the *external malleolar* itself sends little twigs to the joint; sometimes a supply is derived from both sources. The *internal malleolar* branch of the anterior tibial sends in small twigs through the anterior and internal lateral ligament. The *posterior tibial* supplies a well-marked branch as it curves round the inner ankle, which pierces the ligament beneath the posterior tibial tendon; and another branch comes off higher up, and enters the joint close below the edge of the tibia, near the base of the malleolus. The *posterior peroneal* contributes a branch which pierces the posterior ligament close to the fibular attachment of the external lateral ligament.

NERVES.—The ankle-joint is supplied with nerve-twigs from (1) the internal saphenous, a branch from which given off in the leg descends along the margin of the tibia, and sends filaments into the ankle-joint in front of the inner malleolus: (2) the external division of the anterior tibial nerve. By the first source the ankle-joint is brought into association through the anterior crural with the lumbar plexus, and by the second through the sciatic trunk with the sacral plexus.

BURSÆ.—The bursæ about the ankle, like those about the wrist, and in fact about ginglymoid joints in general, are of the vaginal, not of the vesicular form, *i.e.*, they are sheaths formed by the reflection of the synovial-like membrane from the fibrous sheath of the tendon on to the tendon itself, and not simple globular sacs placed between bone and tendon, without enveloping the tendon. Usually the only vesicular bursa about the ankle is one between the os calcis and tendo Achillis; occasionally others are connected with the flexor longus pollicis. The lower part of the anterior annular ligament, which binds down the four tendons in front of the ankle, is divided into three compartments, within each of which tendons play over the joints in loose synovial sheaths. Thus there is one for the tibialis anticus, another for the extensor longus pollicis, and a third common to the extensor longus digitorum and peroneus tertius. *Behind the ankle* there is a bursa common to both the peroneus longus and brevis tendons, between them and the lower end of the fibula, as low down as the apex of the malleolus. This continues inwards upon the peroneus longus as far as the sole of the foot, but in front of the malleolus and between the tendon and the os calcis there is a bursa proper to the peroneus brevis. There is a loose synovial sheath or bursa, like those in which the muscles in front of the ankle and the peroneal muscles play, for the flexor longus pollicis; this extends over

PLATE XX

BURSÆ BETWEEN THE FRONT OF ANKLE JOINT & LOWER
OF TIBIA, AND THE TENDONS PASSING OVER THE JOINT.

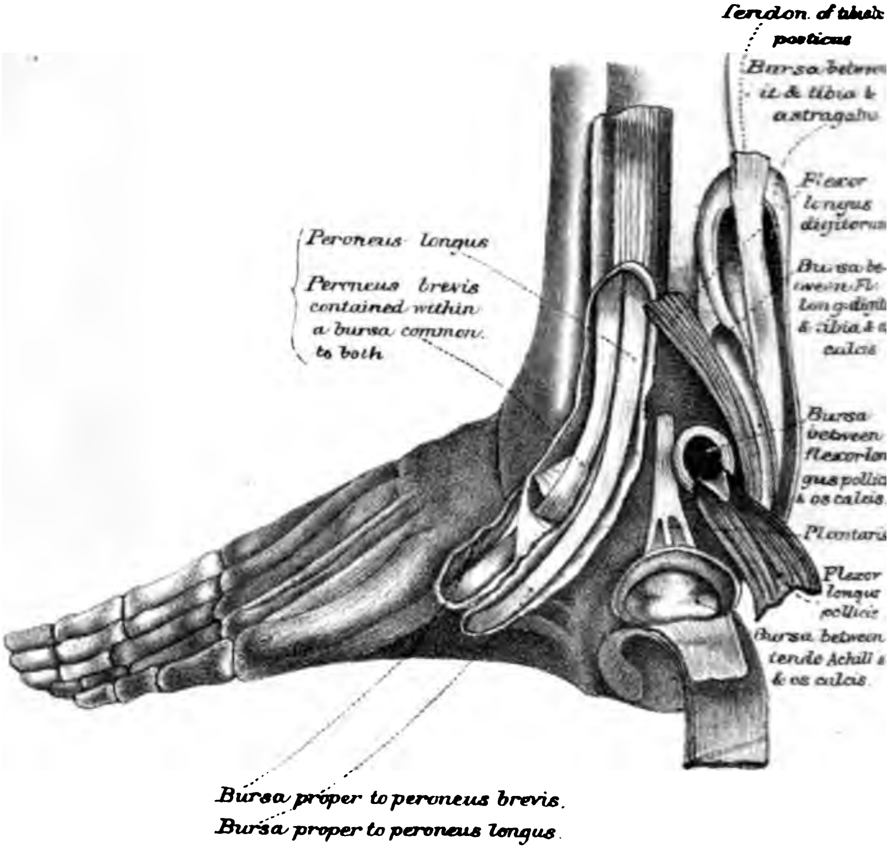


A. Hensman del: after Monro

West, Newm

PLATE XL.

BURSÆ AT THE BACK OF THE HEEL & OUTER & INNER SIDES OF ANKLE JOINT



A. Hen[illegible]fter Monro.

West, Newman & Co. Lith

the tendon from some distance above the lower end of the tibia to beyond the groove in the sustentaculum tali.

Similarly there is a bursa to ease the play of the flexor communis digitorum over the lower end of the tibia, the internal lateral ligament, and os calcis; and of the tibialis posticus tendon over the tibia, internal lateral ligament, and head of ths astragalus, as far as the tubercle of the scaphoid.

Although not in direct connexion with the ankle-joint, this seems the best place to mention the synovial sac, or bursa, between the tendo Achillis and the upper and back part of the os calcis. Part of the wall of this bursa is often much thickened with fat, into which the tendon of the plantaris is partly inserted. It has been said of this little muscle, that one of its uses is to compress this fatty tissue of the bursa.

MUSCLES.—All the muscles which arise from the tibia and fibula pass over the ankle, some to be inserted into the tarsus and metatarsus, and others into the digital phalanges. Only two muscles which arise above the knee pass beyond the ankle; these are the gastrocnemius and plantaris, which, arising from the condyles of the femur, are inserted with the soleus into the os calcis by means of the tendo Achillis. In all, twelve muscles are in relation to the ankle—viz., in front, the tibialis anticus, the extensor longus pollicis, extensor communis digitorum, and peroneus tertius; behind the outer ankle, the peroneus longus and brevis, which rest on the posterior and middle portions of the external lateral ligament, the brevis lying nearest to the joint; behind the inner ankle, from the malleolus to the heel, the tibialis posticus, the flexor longus digitorum, and the flexor longus pollicis; and lastly, the three muscles which go to the os calcis.

The tibialis anticus and posticus, and the peroneus longus, brevis and tertius, are inserted into the tarsus and metatarsus. The two former acting together raise the inner border of the foot and adduct it; the three latter acting together raise the outer border of the foot and abduct it.

The tibialis anticus and peroneus tertius acting together flex the foot on the leg, *i.e.*, draw up the dorsum of the foot towards the front of the leg; whereas the peronei longus and brevis and tibialis posticus extend the foot. The tibialis posticus, owing to its wide insertion into the bones and ligaments of the tarsus, and the peroneus longus by crossing obliquely from the outer border of the tarsus to the inner border of the metatarsus, assist materially in supporting the transverse as well as the longitudinal arches of the foot; the former assists also several ligaments in holding the various bones of the tarsus together.

The flexor longus digitorum, flexor longus pollicis, extensor communis digitorum, and extensor longus pollicis are inserted into the phalanges. The two former flex their respective toes; and when this action is either completed or prevented, they assist the tibialis posticus and peronei longus and brevis to extend the ankle. The oblique direction in which the flexor longus digitorum enters the foot is corrected by the musculus accessorius, which, besides altering the line of action of the muscle, increases its power upon the toes, and gives a fixed point to the long tendon when acting on the ankle-joint. The extensors of the toes also assist the tibialis anticus and peroneus tertius to flex the ankle-joint when their action on the phalanges is either prevented or completed.

The muscles of the calf are the powerful extensors of the foot, by means of which chiefly the heel is raised and the weight of the body is thrown on to the ball of the foot, as in walking, leaping, and running. The gastrocnemius, besides acting with the soleus as an extensor of the ankle, is a flexor of the knee, when the ankle is fixed by the muscles passing over the front of that joint.

MOVEMENTS.—Although it has been stated that certain muscles turn the inner border of the foot upwards and move it inwards, and that others turn the outer border upwards and move the foot outwards, these movements do not occur at the ankle-joint. This is a true hinge-joint, and flexion and extension are the only movements of which it is capable. No lateral movement whatever is permitted, except the very slightest, when the foot is in a state of extreme extension, and thereby the narrowest part of the astragalus is thrown forwards into the widest part of the tibio-fibular arch.

The ligaments which limit flexion are—(1) nearly the whole of the internal lateral ligament, none but the most anterior fibres of it being relaxed; (2) the posterior and middle portions of the external lateral ligament, but especially the posterior portion; (3) the posterior ligament of the joint.

Flexion is also limited by the neck of the astragalus pressing against the edge of the tibia.

Extension is limited (1) by the anterior fibres of the internal lateral ligament; (2) the anterior and middle portions of the external lateral ligament; and (3) the inner fibres of the anterior ligament. Extension is also checked by the posterior part of the astragalus meeting with the back of the tibia. The middle portion of the external lateral ligament is always on the stretch owing to its obliquely backward direction, whereby it limits flexion; and its attachment to the fibula in front of the apex of the malleolus, whereby undue extension is prevented as soon as the toes begin to twist inwards. This twisting inwards of the toes in extreme extension is partially due to the greater posterior length of the inner border of the superior articular surface of the astragalus and to the lesser proportionate height posteriorly of the outer border of that surface, the hindermost part of which is, in extension, brought into the tibio-fibular arch; but partly also to the lateral movement in the calcaneo-astragaloid joints.

Flexion and extension take place round a transverse line drawn through the body of the astragalus. The movements are not in a direct antero-posterior plane, but along a plane inclined outwards and drawn through the foot from the middle of the astragalus to the apposed surfaces of the bases of the second and third metatarsal bones. This oblique plane corresponds to the outward inclination of the toes, to the slight twisting of the shaft of the tibia, and to the posterior position of the external malleolus.

CHAPTER XX.

THE JOINTS AND LIGAMENTS OF THE FOOT.

THE foot forms the inferior segment of the lower limb, and is placed at a right angle to the leg at the ankle-joint. It is thus horizontal in direction when the body is erect, indeed this relation of the foot to the leg, like the similar relation of the head to the spine, is an adaptation of the erect attitude of man. In scarcely any animal, except man, is there a similar disposition of the foot to the leg. Moreover, the human foot is distinguished from that of the quadrumana and other animals (1) by the small size of its phalanges, (2) by the relatively larger size of the tarsus; (3) by the great strength of the pollex, which is able to bear a considerable part of the weight of the body; (4) by the position of the pollex in front of the tarsus, and its parallelism with the other toes, instead of being set off at an angle like the thumb; and (5) by the secure manner in which the bones of the tarsus are bound together, and to the metatarsus by strong ligaments, whereby they form a double arch upon which the body can be supported with steadiness, or move with elasticity and ease.

The size of the foot varies in different individuals. It always exceeds the hand in length and thickness, but should fall short of it in width. The shape of the foot is ovoidal, with its long axis from before backwards. It consists of three segments of different constructions, and named in order from behind forwards, the tarsus, metatarsus, and phalanges or toes.

The toes are much smaller and weaker than the fingers. They enlarge the area of the foot, confer upon it some amount of clinging or grasping power, and add to the elastic spring of the foot through the agency of their joints and tendons. Their small size is a characteristic feature of the human skeleton.

Practically they are almost useless amongst civilised races, owing to their confinement within the close limits of boots; but, in primitive states, and in those in which shoes are not employed, they are of service in climbing, and, by their capacity for clinging to inequalities of surface, they prevent slipping during the act of walking upon uneven ground. Occasionally they have been turned to great and varied uses by persons deficient of hands; but these cases are altogether exceptional, and in the ordinary way the phalanges in man are quite unnecessary to the well-being of the individual.

The tarsus and metatarsus are much more solid, and vastly stronger than the phalanges, but they do not equal them in their degree of mobility. Although the phalanges of the foot are so much smaller, and so much less mobile, than the corresponding parts in the hand, the tarsus and metatarsus are larger, stronger, and of more significance in every way than their corresponding parts in the hand. In other words, the degree of importance of different parts of the hand is inverse to that of the homologous parts of the foot; the anterior portion of the former, and the posterior of the latter, possessing the most striking characters and the chief value.

The foot is indeed like the hand in certain respects, but is modified so as to serve as a basis of support, whereas the hand is adapted, not for the purpose of bearing weight (though this it is able to do to a considerable degree), but of accomplishing rapid, varied, and delicate movements. Both hand and foot possess great elasticity, but one of the most striking modifications of the foot is the great size and strength of the metatarsal bone of the great toe, and its mode of articulating with the tarsus, whereby only a very limited degree of movement is permitted.

In animals which use the distal segment of both anterior and posterior extremities for prehension, *e.g.*, the quadrumana, these segments in all four extremities are developed like thumbs; the foot cannot bear weight without the assistance of the hand, and the several parts of the foot are less closely adapted to one another, and form much less perfect arches.

The arches of the human foot are formed entirely by the tarsus and metatarsus combined, the phalanges taking no share in them; they are two in number—an antero-posterior, and a transverse.

The antero-posterior arch has its summit at the top of the astragalus, where that bone articulates with the tibia to form the ankle-joint. Its hinder limb, or pier, is formed by the back of the astragalus, and somewhat more than the posterior half of the os calcis; while the anterior limb, or pier, is formed by the anterior parts of the astragalus and os calcis, by the other tarsal bones, and by the metatarsus.

Thus, when the foot is planted firmly on the ground it rests upon the point of the os calcis behind, and upon the anterior extremities of all the metatarsal bones in front, as well as upon the outer border of the foot.

These two piers differ from one another strikingly in width, length, solidity, inclination from the summit of the arch, in the number of articulations formed by them, and, as a consequence of the latter difference, in their degree of elasticity.

The hinder pier measures about one inch and a half in width, and from two and a half to three inches in length, being just about half the width and length of the anterior pier. The inclination of the hinder pier to the vertical line drawn through the centre of the astragalus makes an angle of about 40°, whilst the angle made by the anterior pier with this line is between 70° and 75°. The hinder pier is nearly solid, being broken by the line of one articulation only, viz., the calcaneo-astragaloid; by this construction the muscles of the calf which raise the foot act at once upon the ankle-joint, without being weakened by any moving surfaces between their insertion and point of action.

The anterior pier is composed of many articulations, viz., tarsal, tarso-metatarsal, and metatarsal; and by means of these several joints and their ligaments, an elasticity and spring are given to the foot, which are of great use in leaping, running, and walking; whilst concussions are broken or prevented by them. The anterior pillar widens out as it extends forwards, and thus the jarring effects of shocks are diminished by their distribution over a wider area. The difference in the capacity of these two piers to prevent shocks to the foot, or rest of the body, is experienced in jumping from a height; if we alight upon the hinder pier, an unpleasant shaking occurs, which is but rarely felt, and then to a less extent if we descend upon the balls of the toes. The anterior pier of the arch may be regarded as composed of two divisions, an inner and an outer; the inner is formed by the astragalus, scaphoid, the three cuneiform, and the three inner metatarsal bones; and the outer by the os calcis, cuboid, and fourth and fifth metatarsal bones. The tarsal part of the inner division is less solid than that of the outer; but it is more elastic, and to it the chief part of the weight of the body is transmitted directly from the astragalus, and is conveyed forwards to the balls of the three inner toes.

The metatarsal portion of the inner division, owing to the great size of the first metatarsal bone, is much more solid than the corresponding part of the outer division of this pier. The second metatarsal bone is the longest of all, whilst the two sesamoid bones of the metatarso-phalangeal joint of the great toe compensate for the diminished length of the first metatarsal bone. Possibly the second metatarsal bone touches the ground before the balls of any of the other toes, except the fifth; if so, it would explain the wearing away of the soles of the boots beneath this part of the foot. Practically, it must be understood, when the foot is firmly resting on the ground, the weight of the body is borne upon the extremities of all the metatarsal bones, and not simply upon those of the first and fifth, as has been sometimes stated.

The inner division is much more highly arched than the outer, especially in its tarsal portion. The outer division bears less weight, and this is transmitted to it indirectly from the astragalus through the os calcis. It forms a lateral support or stay to the inner division. The inner border of the foot taken as a whole is concave, the outer border is convex; and from heel to balls of toes there is an inclination of the whole foot outwards—an arrangement well adapted for receiving weight from the leg which is directed inwards.

The transverse arch, which is most marked across the cuneiform bones, like the antero-posterior, gives elasticity to the foot, and provides for the safe lodgment of the vessels and nerves of the sole; the arches result from the shape of the articular surfaces of the bones, and their integrity is maintained by the fasciæ of the sole of the foot, the strong ligaments of the tarsus and metatarsus, the decussation of the tendons of the tibialis posticus and peroneus longus, by the small muscles of the sole, and by the tibialis anticus.

The foot is composed of twenty-eight bones, arranged in three divisions, named from behind forwards, the tarsus, metatarsus, and phalanges. In the tarsus there are seven bones, ten articulations, and four synovial sacs; in the metatarsus there are five bones, three articulations, but no separate synovial sac. Between the tarsus and metatarsus there are five articulations, with one separate synovial sac, and two synovial sacs in common with those between the several tarsal and metatarsal bones. There are fourteen phalanges, forming nine inter-phalangeal articulations, each joint having its own synovial sac; and finally, there are five metatarso-phalangeal joints, each with its own synovial sac. The bones of the tarsus articulate with one another, and four of them with the metatarsus; the four outer metatarsal bones articulate laterally with one another; the phalanges of the second row articulate at their bases with the heads of the phalanges of the first row, and at their heads with the bases of the phalanges of the third row; whilst the phalanges of the first row articulate by their bases with the metatarsal bones of their own toes, and those of the third row taper off at their distal ends into flattened, rough, non-articular surfaces.

The inter-tarsal articulations, with only one exception, are of the arthrodial character; they may be divided into (1) those which unite the posterior bones of the tarsus, viz., the posterior and anterior, calcaneo-astragaloid; (2) those which unite the anterior bones of the tarsus with one another, viz., the three scapho-cuneiform, the two inter-cuneiform, the cubo-cuneiform, and cubo-scaphoid; and (3) into those which unite the two bones of the posterior portion of the tarsus with two of the bones of the anterior portion of the tarsus, viz., the astragalo-scaphoid and the calcaneo-cuboid; these two together form what is commonly called the medio-tarsal articulation.

The Joints and Ligaments of the Posterior Part of the Tarsus, or the Calcaneo-astragaloid Articulations.

Class, Diarthrosis. *Subdivision*, Arthrodia.

The os calcis articulates with the astragalus by a double joint, the anterior and posterior; the anterior communicates with the medio-tarsal articulation; the posterior is separate and complete in itself.

The Posterior Calcaneo-astragaloid Joint.

The Os Calcis presents on its superior surface two articular facets of unequal size, of different aspects, and separated from one another by a deep groove. Besides the two articular facets and the groove between them the upper surface of the bone is characterised by a (*a*) large non-articular portion behind; (*b*) by an inwardly projecting process, partly articular and partly non-articular, called the sustentaculum tali, in front of the inner extremity of the groove; and (*c*) by a sudden alteration in the level of the surface, so that the anterior third is one inch lower than the posterior two-thirds, owing to the difference in the vertical thickness of the bone. The posterior and larger facet is convex, situated somewhat in front of the middle of the upper surface, and articulates with the large concave posterior articular facet on the under surface of the astragalus. It occupies in part the elevated portion of this surface, but chiefly the precipitous surface formed by the sudden alteration in the levels of the anterior and posterior portions of this bone; the facet is oblong in form, with its long diameter directed obliquely outwards and forwards; it stretches across the whole width of the calcis, and looks upwards with a very considerable inclination forwards. Indeed, when the bone is examined separately, and placed with its under surface on a flat table, the anterior and outer two-thirds of the facet look almost directly forwards, while the posterior and inner one-third looks upwards and inwards. This inclination of the facet is somewhat altered in the articulated foot, owing to the long axis of the os calcis being directed upwards and outwards from the heel, on account of the bone entering into the formation of the antero-posterior arch of the foot. The posterior part of this facet slopes downwards and forwards on the inner side of the bone, so as to approach the sustentaculum tali. From the inwardly projecting posterior edge of this process the facet is only separated by the very narrow inner end of the interosseous groove. Between the facet and this end of the sustentaculum tali there is a cup-like concavity, into which the projecting posterior, inferior, and internal angle of the astragalus is received in certain positions of the foot, as when the heel is raised in walking; whilst the angle of the astragalus becomes wedged against the sustentaculum tali. Again, in front of the outer end of the interosseous groove the upper surface is somewhat raised, so that a cup-like depression is formed between the lower and outer end of the large facet and the non-articular front part of the upper surface of the calcis; into this depression the anterior, inferior, and external angle of the astragalus is received in certain positions of the foot, as when the heel is raised in walking. Thus these parts of the calcis act as strong stops or checks, against which the astragalus is pressed when the heel is raised, and the weight of the body is directed from the vertical into the obliquely forward direction.

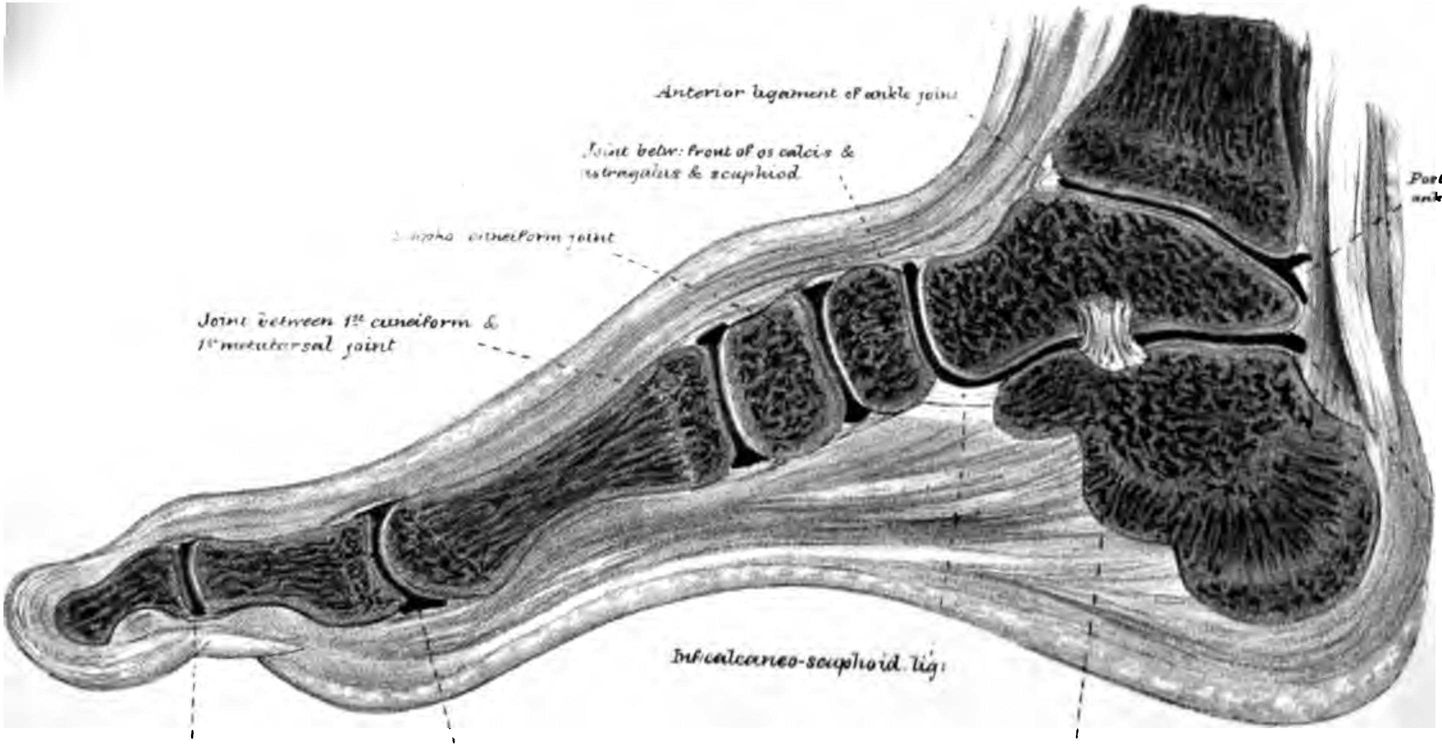
The interosseous groove is narrow at the inner end, and widens as it proceeds outwards; it extends obliquely forwards and outwards from the inner to the outer edge of the os calcis. This groove, with a similar one on the under surface of the astragalus, forms the sinus pedis, and gives attachment to the strong interosseous ligament which connects the two bones together.

The ASTRAGALUS presents on its inferior surface two articular facets separated by a deep rough groove: the *posterior facet* articulates with the posterior facet on the body of the os calcis; it is much the larger of the two, and extends obliquely across the whole width of the bone, being about one inch and a half in length, and nearly three-quarters of an inch in width. It looks downwards and backwards, has its long axis obliquely forwards and outwards, in which direction it is concave, while it is flat, or nearly so, from side to side. Its hinder part is broader than its anterior extremity; its posterior edge forms one of the boundaries of the groove for the flexor longus pollicis tendon, its external edge is separated by a narrow groove from the articular surfaces for the tibia and external malleolus, and its anterior edge limits the interosseous groove. Overhanging this passage on the inner side of the bone, and forming a prominent edge to the groove for the flexor longus pollicis, is a projecting angle of bone, which in certain positions is pressed forwards against and resisted by the posterior edge of the sustentaculum tali. Again, another angle projects beyond the anterior and external extremity of the facet, and is resisted by the elevation on the upper surface of the body of the os calcis. In this way the forward and inward displacement of the astragalus by the weight of the body when the heel is raised is prevented; and in the same way the weight is distributed to the cuboid and two outer metatarsal bones through the calcaneum from the astragalus.

THE LIGAMENTS.—The ligaments in connexion with the posterior calcaneo-astragaloid joint form a complete capsule. They consist of the interosseous ligament, which is the chief

PLATE XLI

SECTION OF THE ANKLE AND FOOT THROUGH THE LINE OF THE GREAT TOE


Anterior ligament of ankle joint
Joint betw: front of os calcis & astragalus & scaphiod
Scapho cuneiform joint
Joint between 1st cuneiform & 1st metatarsal joint
Post. lig: of ankle joint
Inf: calcaneo-scaphoid lig:
Phalangeal joint
Metatarso-phalangeal joint of great toe
Interosseous calcaneo astragaloid lig:
Post: calcaneo-astragaloid joint

bond of union between the bones, forming the anterior portion of the capsule, and of the external, internal, and posterior calcaneo-astragaloid ligaments.

The *interosseous calcaneo-astragaloid ligament* is the strong band connecting the opposed surfaces of the os calcis and the astragalus along their oblique grooves. It is composed of several vertical laminæ of fibres, sometimes ten or more may be distinctly seen, amongst which is a quantity of fatty tissue. This ligament is much deeper and broader, and better marked towards the outer end than elsewhere. Strong laminæ of fibres reach between the rough superior surface of the anterior extremity of the os calcis, and the rough external and inferior surface of the neck of the astragalus. They have sometimes been described as the *anterior interosseous ligament*, and they form the posterior boundary of the anterior calcaneo-astragaloid joint. The most posterior laminæ occupy the hinder part of the sinus pedis, and extend downwards and backwards from its roof to the os calcis immediately in front of the large facet for the astragalus. They thus form the anterior part of the capsule of this joint.

The *external calcaneo-astragaloid ligament* extends between the bones on their outer side. It is attached to the groove on the side of the astragalus near its lower margin, and to the os calcis at some little distance below the edge of the articular surface. The middle portion of the external lateral ligament of the ankle-joint passes over and strengthens it. The interval between the anterior and middle portions of the external lateral ligament of the ankle is occupied by the fibres of this calcaneo-astragaloid ligament; and a considerable fasciculus of its fibres passes from the astragalus to blend with the middle portion of the ankle-joint ligament along its anterior border.

The *posterior calcaneo-astragaloid ligament* passes from the process of bone behind the groove for the flexor longus pollicis, and from the lower edge of that groove downwards and backwards to the rough superior surface of the os calcis at a variable distance behind the margin of the large articular facet. The space between the posterior calcaneo-astragaloid ligament and the tendo Achillis is occupied by a quantity of fatty tissue.

The *internal calcaneo-astragaloid ligament*, a narrow strip of very short but well-marked fibres, passes obliquely downwards and backwards from a depression upon the astragalus immediately behind the inner extremity of the sinus pedis to the os calcis, behind the sustentaculum tali. This ligament therefore completes the floor of the groove for the flexor longus pollicis tendon. It must be remembered that owing to the obliquity of the articular surfaces and the sinus pedis, the inner border of this posterior calcaneo-astragaloid joint is necessarily very small.

The SYNOVIAL MEMBRANE is distinct from any other synovial sac.

THE ARTERIES.—1. A branch passes into the interosseous canal on the inner side, from the posterior tibial artery, and supplies the structures of this joint. 2. Other twigs are derived from a branch of the tarsal artery which enters the interosseous canal on the outer side. 3. The external malleolar of the anterior tibial; and (4) the terminal branches of the peroneal artery supply articular branches to it on the outer side.

THE NERVES.—The posterior tibial, or one of the plantar branches into which it divides.

BURSÆ.—The bursæ of the tendons which pass over the back of the ankle-joint extend also over the line of this articulation.

The Anterior Calcaneo-astragaloid Joint.

This joint is bounded behind and on each side by ligaments, but is incomplete in front where it communicates with the astragalo-scaphoid articulation. It is formed between the anterior articular facet on the upper surface of the os calcis and the facets on the lower surface of the neck and head of the astragalus.

OS CALCIS.—The anterior facet on the superior surface of this bone is separated from the posterior by the interosseous groove and by the rough anterior portion of its upper surface. It is internal to and narrower than the posterior facet, and is longitudinally concave, instead of being convex, like the posterior. It is oblong in shape, has its long diameter inclined forwards and outwards, and its surface looking upwards and forwards. It occupies chiefly the superior aspect of the sustentaculum tali, but in part also the anterior internal edge of the upper surface of the body of the os calcis. The portion upon the sustentaculum tali articulates with the facet on the under surface of the neck of the astragalus, the portion upon the body of the bone articulates with the small facet on the lower and outer part of the head of the astragalus; these two portions are sometimes separated by a narrow rough depression, which corresponds to a slight ridge on the apposed surface of the astragalus, separating the facet on the neck from that on the lower and outer side of the head of that bone.

ASTRAGALUS.—The anterior articulating facet on the inferior surface of this bone for the os calcis occupies, as has been said above, partly the neck and partly the lower aspect of the head. Its long axis is obliquely forwards and outwards; its surface is directed backwards and downwards, and it is convex to suit the corresponding concavity of the apposed facet of the os calcis. It is divided into two parts by a short ridge which runs obliquely forwards and inwards, and together with a constriction in the hinder border of the facet corresponds to the groove on the apposed surface of the os calcis. The portion on the outer side of the ridge rests in part on the body of the os calcis, and in part on the calcaneo-scaphoid ligament, whilst in the movements of the bones it slides backwards and forwards on both. The inner and larger part of this facet is often separated by a small non-articular interval from the facet on the rounded head for the scaphoid.

THE LIGAMENTS.—The ligaments are situated on the posterior, internal, and external aspects of the joint. Anteriorly there is no ligament, for here it is continued into the astragalo-scaphoid articulation.

The *interosseous calcaneo-astragaloid ligament* by its anterior laminæ limits this articulation posteriorly. It has been described under the posterior calcaneo-astragaloid joint.

The *internal calcaneo-astragaloid ligament* consists of short fibres attached above to the rough depression on the internal surface of the neck of the astragalus, and below to the inner free border of the sustentaculum tali close to its upper margin. These fibres are blended posteriorly with the inner extremity of the interosseous ligament, and anteriorly with the upper border of the calcaneo-scaphoid ligament on its deep aspect. They are strengthened by the internal lateral ligament of the ankle-joint, part of the fibres of which are attached to the calcaneo-scaphoid ligament on its superficial aspect.

The *external calcaneo-scaphoid ligament* limits this as well as the astragalo-scaphoid joint on the outer side. It consists of a separated from it by a rough depressed and somewhat constricted surface—viz., the upper aspect of the neck. Below, the surface for the scaphoid is separated by only a narrow rough and non-articular interval (which extends obliquely backwards and inwards) from the facet on the under surface of the neck for the sustentaculum tali; but it is continuous with that which articulates with the anterior internal angle of the upper surface of the body and with the upper surface of the calcaneo-scaphoid ligament.

The articular surface of the head which fits into the socket of the scaphoid is convex from side to side and from above downwards; it is two inches from side to side, and is prolonged further back on the inner aspect than on the outer, so that when the foot is in a position of rest the scaphoid does not cover the whole of the articular surface by half an inch or more on its inner side, though it extends quite to the limit of the facet on the outer side. From above downwards the surface measures at its middle one inch, but towards the outer and inner extremity it is not quite so deep; and at the inner end, which is shallower than the outer, the vertical measurement is barely half an inch. On the inner surface of the astragalus, behind the inner end of the articular facet for the scaphoid, there is a rough depression for the attachment of some of the fibres of the internal lateral ligament of the ankle-joint.

THE SCAPHOID.—The posterior surface of the scaphoid presents a large doubly concave articular surface, measuring a little over an inch from side to side, and being deeper on the outer side, where it measures three-quarters of an inch from above downwards, than on the inner side, where it does not measure more than a quarter of an inch. The whole of this surface of the scaphoid, except a narrow vertical triangular portion at the inner end which corresponds to the back of the tubercle of the scaphoid, is articular.

THE LIGAMENTS.—Three ligaments assist in keeping the posterior concave surface of the scaphoid in contact with the head of the astragalus. Of these one has been already described, viz., the external calcaneo-scaphoid, under the ligaments of the anterior calcaneo-astragaloid joint. The other two are the inferior calcaneo-scaphoid on the plantar surface, and the astragalo-scaphoid ligament on the dorsal surface.

which pass over it on the inner side, are the flexor longus pollicis, the flexor communis digitorum, and the tibialis posticus. The muscles of the leg which pass over the front of the ankle and move the foot upon the astragalus, are the tibialis anticus, the extensor proprius pollicis, the extensor longus digitorum, and the peroneus tertius.

The astragalus is grooved by the flexor longus pollicis, but no muscle is attached to it. Of these several muscles, those which pass from heel to toes cannot produce any definite movement except by depressing the heel and causing the os calcis to glide forward and inward beneath the astragalus, whereby the arch of the foot is increased.

Elevators of the Heel.—The muscles which raise the heel and extend the ankle, are the tendo Achillis, tibialis posticus, the flexor longus pollicis, the flexor communis digitorum, and peroneus longus. When the heel is raised by these muscles, the astragalus, by the weight of the body, is made to slide forwards on the os calcis.

Depressors of the Heel.—In addition to the muscles of the sole above referred to, others besides depress the heel. The muscles which pass over the front of the ankle raise the toes and flex the ankle-joint, and when the heel is kept in contact with the ground, the astragalus in this position of the foot is made to slide backwards on the os calcis by the superincumbent weight of the body.

Adductors and Inward Rotators of the Foot beneath the Astragalus.—The tibialis posticus, the flexor longus pollicis, and flexor longus digitorum, which pass behind the inner malleolus; and the tibialis anticus, and extensor longus pollicis, which pass in front of it, produce adduction or inversion, *i.e.*, turn the inner side of the foot upwards, and rotate the toes inwards and the heel outwards.

Abductors and Outward Rotators.—The peroneus longus and brevis which pass behind the external malleolus, and the peroneus tertius and the outer tendon of the extensor longus digitorum which pass in front of it, help to turn the outer border of the foot upwards, *i.e.*, abduct or evert it, and rotate the toes outwards and the heel inwards.

THE MOVEMENTS BETWEEN THE ASTRAGALUS AND OS CALCIS.—The movements which occur between the astragalus and os calcis are so intimately associated with those which take place at the medio-tarsal joint, *i.e.*, between the astragalu and os calcis behind, and scaphoid and cuboid in front, tha they might fitly be described together. It will, however, b more convenient to consider them separately. The joint between the os calcis and astragalus permit of adduction an abduction, with some rotation of the foot beneath the astragalus, and thereby increase the variety and range of th movements of the foot upon the leg, which at the ankle-join are limited almost entirely to flexion and extension. Thes movements between the astragalus and os calcis take plac around an axis drawn in an antero-posterior direction, throug the under surface of the astragalus, at right angles to th axis of motion at the ankle-joint. Adduction and abductio of the foot upon the astragalus are combined with som rotation, which occurs in a nearly horizontal plane; adduction or inclination of the sole inwards being associate with a turning of the toes inwards, and of the heel outward while abduction or inclination of the sole outwards is associated with a turning of the heel inwards and of the toe outwards. In these movements the cuboid moves wit the os calcis, and the scaphoid, carrying with it the bones i front of it, revolves upon the rounded head of the astragalu As abduction and adduction cannot occur without some rotation, so rotation cannot occur without some adduction o abduction.

The shape of the articular facets of the two bones allows o neither true lateral nor true rotatory movements. In walking when the foot is placed upon the ground, the heel is the firs part to make contact, and the foot is slightly adducted beneat the astragalus. As the body is swung forwards to the vertica position, first the outer toes and then the inner touch the surface, whilst the head of the astragalus presses forwards agains the scaphoid and sinks downwards upon the calcaneo-scaphoi ligament, the foot meanwhile becomes slightly abducted beneat the astragalus. When the foot is firmly placed upon th ground it has to bear the weight of the body, which is transmitted to it in an oblique direction from above downwards an inwards; this being so, if the ligaments between the astragalu and os calcis and the internal lateral ligament of the ankle joint did not check abduction, inward displacement of th astragalus from beneath the arch of the leg bones would onl be prevented by the tendons passing round the inner ankle. So far, however, from the astragalus and inner ankle being entirely dependent for support upon these tendons, they also enjoy the extra security afforded by the ligaments; but when these ligaments are too weak to limit abduction, the weight of the body increases it, and forces the inner malleolus and the astragalus downwards and inwards, and gives rise to the condition known as flat foot; and if in addition, as sometimes is the case, the peronei muscles are contracted so as to draw the os calcis and rest of the foot outwards and upwards, or if the tibialis anticus is wasted and paralysed so as no longer to assist in keeping up the arch of the foot on the inner side, talipes valgus complicates the flatness of the foot.

The advantages of the obliquity and peculiar arrangement of the articular surfaces of the posterior calcaneo-astragaloid joint become apparent from a consideration of the movements which occur in the act of walking. When the foot is advanced in front of the body the heel is first planted on the ground, and the whole weight is thrown upon the back of the foot, *i.e.*, upon the heel bone, as it is received upon the posterior facet of the os calcis. When the body has been carried forwards, and the toes touch the ground, the large articular facet of the os calcis pushes against the astragalus as the heel is being raised, so as to transfer the weight of the body on to the ball of the toes, whilst the hinder edge of the sustentaculum tali, and the anterior and outer part of the upper surface of the os calcis, prevent the astragalus from being displaced too far forwards by the superincumbent burden; thirdly, whilst the heel is kept raised by muscular action and the other foot is swung forwards, and before the toes leave the ground, the os calcis serves to suspend the weight of the body by the pressure of the astragalus against the hinder edge of the sustentaculum tali and the upper and anterior part of the body of the os calcis. In this way the weight is distributed through the os calcis to the cuboid and outer division of the metatarsus, as well as through the head of the astragalus to the scaphoid, and through the latter to the cuneiform bones and the inner division of the metatarsus.

The Joints and Ligaments of the anterior part of the Tarsus; or, The Cubo-scaphoid, Scapho-cuneiform, Inter-cuneiform, and Cubo-cuneiform Articulations.

Class, Diarthrosis. *Subdivision*, Arthrodia.

The bones in front of the astragalus and os calcis are arranged in two transverse rows, into each of which the cuboid enters. These rows are placed one in front of the other; thus we find the scaphoid and cuboid united to each other, forming the whole width of the tarsus and entering into the medio-tarsal joint by their posterior surfaces, while in front of the scaphoid are placed the three cuneiform bones, which, together with the cuboid, also occupy the whole width of the tarsus, and enter into the formation of the tarso-metatarsal joints by their anterior surfaces. These several bones are united by ligaments with one another, so as to form one firmly and closely united but yielding structure, in which are found no less than seven articulations.

The Union between the Scaphoid and the Cuboid.

THE SCAPHOID.—The narrow *outer end of the scaphoid* is united with the posterior part of the internal surface of the cuboid by ligaments passing between the dorsal, plantar, and apposed surfaces of the bones. This surface of the scaphoid is rough and convex, but has occasionally a minute facet for the cuboid towards its anterior part which is continuous over a sharp edge with the surface on the same bone for the external cuneiform bone.

THE CUBOID.—The *inner surface of the cuboid* looks inwards, upwards, and a little forwards; and presents upon its posterior third a deep rough depression for the attachment of an interosseous ligament—viz., the cubo-scaphoid; surrounding this depression is a rough ridge which is very prominent above and in front, and separates it from the facet for the outer cuneiform bone. Sometimes a second small cartilage-covered surface is present immediately behind this larger facet; this is for the scaphoid. When the scaphoid and cuboid are in contact, the cubo-scaphoid interosseous ligament is behind the articular facets, whilst the facets themselves are continuous with other facets on the respective bones for the external cuneiform. The posterior inferior and internal angle of the cuboid forms a large rounded tubercle which projects backwards beneath the os calcis, and inwards beneath the outer end of the scaphoid. The latter is supported by the tubercle, with only the intervention of their uniting ligaments. The scaphoid and cuboid together form a well-marked transverse arch, the highest point of which is at the junction of the outer and middle thirds of the dorsum of the scaphoid. The outer pier of this arch, which is the tubercle or outer end of the ridge of the cuboid, descends much lower than the inner pier which is formed by the tubercle of the scaphoid.

LIGAMENTS CONNECTING THE TWO BONES OF THE SECOND ROW OF THE TARSUS TOGETHER.—The *dorsal cubo-scaphoid ligament* runs forwards and outwards from the outer end of the dorsal surface of the scaphoid to the middle third of the inner border of the cuboid on its dorsal aspect. It passes over the posterior external angle of the outer cuneiform bone, and is wider towards its outer than at its scaphoid attachment.

The *plantar cubo-scaphoid ligament* is a well-marked and strong band taking the same oblique course forwards and outwards to the cuboid as does the dorsal ligament. It is attached to the plantar surface of the scaphoid some distance external to the tubercle, and to the depression on the inner side of the cuboid, and slightly into the plantar surface of the cuboid immediately below this depression.

The Interosseous Cubo-scaphoid Ligament.—A strong ligament passes between the apposed surfaces of these bones from the dorsal to the plantar ligaments. Some of its posterior fibres reach the plantar surface of the foot behind the cubo-scaphoid plantar ligament, radiate outwards and backwards over the inner border of the cuboid to blend with the anterior extremity of the short calcaneo-cuboid ligament.

The Articulation between the Scaphoid and the three Cuneiform Bones.

THE SCAPHOID.—The *anterior surface of the scaphoid,* which is slightly convex from side to side, has curved superior and inferior margins, the convexity of which is upwards and in-between the under surface of the os calcis and cuboid. They are separated by a slight interval occupied by fatty and areolar tissue, where the long overlaps the small ligament.

The *long ligament* is attached behind to the whole of the under surface of the calcaneum between the posterior tubercles and the anterior tubercle. Most of its fibres pass directly forwards, and are fixed to the outer two-thirds or more of the oblique ridge, behind the peroneal groove on the cuboid bone; while some of the fibres pass still further forwards and inwards, expand into a broad layer, and are inserted into the bases of the second, third, and fourth, and inner half of the base of the fifth metatarsal bones. This anterior expanded portion completes the canal for the peroneus longus tendon, and from its under or plantar aspect there arise the adductor pollicis and the flexor brevis minimi digiti muscles.

The *short plantar ligament* is attached posteriorly to the anterior tubercle of the calcaneum and to the bone immediately in front of this; it then takes an oblique course forwards and inwards, and is attached to the whole of the depressed triangular inferior surface of the cuboid behind the oblique ridge, except its outer angle. From the plantar aspect of this ligament the flexor brevis pollicis in part arises. This ligament connects the contiguous edges of the os calcis and the cuboid, and therefore its upper surface is to some extent lined by the synovial membrane of the calcaneo-cuboid joint. It is strongest near the outer edge of the foot.

The long and short plantar ligaments limit extension at the medio-tarsal joint, *i.e.*, of the second row of the tarsal bones upon the first; they are also the chief support of the outer part of the antero-posterior arch of the foot, and indeed the long ligament seems intended to strengthen the rest of the arch also.

They are sometimes unnaturally contracted and give rise to a deformed arching of the foot, commonly called by surgical writers talipes plantaris, which is an abn [illegible] permanent flexion of the foot at the medio-tarsal joi [illegible]

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cubo-scaphoid ligament on the outer side, and passes forwards with an oblique inclination outwards.

The Internal Scapho-cuneiform Ligament.—A very strong thick band connects the tubercle of the scaphoid with the inner surface of the large cuneiform bone. It is continuous with the dorsal ligament above and with the plantar ligament below.

The *plantar scapho-cuneiform ligament* forms, like the corresponding dorsal ligament, a continuous structure extending between the plantar surfaces of the bones. Its fibres are inclined forwards and outwards. To see this ligament and the lower border of the internal scapho-cuneiform ligament, it is necessary to remove the tendon of the tibialis posticus, which lies on their under surface.

The *tendon of the tibialis posticus* sends onwards from the tubercle of the scaphoid to which it has a considerable attachment (1) a strong and compact band to be attached to the base of the internal cuneiform, and especially to the tubercle near the proximal end of the base; (2) a strong fan-shaped expansion, inclined forwards and outwards to be attached to the inner extremity of the oblique ridge of the cuboid, and to the bone in front of the ridge, as well as to the plantar surfaces of the middle and external cuneiform and the bases of their corresponding metatarsal bones; (3) a distinct and almost transverse band passing outwards beneath the peroneus longus tendon across the groove of the cuboid, to be attached chiefly to the inner side of the base of the fifth metatarsal, and slightly to the base of the fourth metatarsal bone, under cover of the long plantar ligament. Over the last-mentioned part of the tendon the long plantar ligament passes on its way to the metatarsal bones; while the tendon of the peroneus longus crosses it nearly at a right angle.

It must be noticed that these expansions of the tibialis posticus tendon, and the ligaments which connect the scaphoid with the cuboid and the cuneiform bones, are inclined forwards and outwards, while the tendon of the peroneus longus and all the ligaments which connect the first with the second row of tarsal bones on their plantar and dorsal surfaces (except the inner half of the dorsal astragalo-scaphoid ligament), are inclined forwards and inwards. The inward inclination of the peroneal tendon, of the short plantar, of the anterior portion of the long plantar, and of the calcaneo-scaphoid ligaments, is very marked; so is the outward inclination of the external part of the tendon of the tibialis posticus, and of the ligaments between the second and third rows of bones. This arrangement is admirably adapted to preserve the arches, and especially the transverse arch of the tarsus. Had these tendons and ligaments run directly forwards, all the strain made by the weight of the body on the transverse arch in standing, walking, and jumping, would have fallen on the interosseous ligaments, whereas by the arrangement referred to the structures passing from within outwards brace up the outer side, and those passing from without inwards brace up the inner side of the arch.

Union of the three Cuneiform Bones with one another, and of the outer Cuneiform with the Cuboid.

THE BONES.—The *inner cuneiform* presents on its outer surface a narrow riband-like articular facet along its upper border, and another at right angles to it along its hinder border. That along the upper border is marked by a vertical ridge at the junction of its middle and anterior thirds; the portion in front of the ridge articulates with the inner side of the base of the second metatarsal bone, that behind, like the whole of the facet along the hinder border, articulates with the inner surface of the middle cuneiform. The rest of the outer surface of this bone is rough for interosseous ligaments.

The *middle cuneiform bone* is marked upon its inner surface by a riband-like facet, which extends the whole length of both upper and hinder borders. The rest of the inner surface is rough for the attachment of an interosseous ligament.

Its outer surface is divided by an oblique line, which extends downwards and backwards from the junction of the anterior and middle thirds of the upper border to the junction of the hinder and middle thirds of the lower border. All the surface behind this oblique line is articular for the external cuneiform, all in front is rough and excavated for the interosseous ligament, except that occasionally there is at the anterior and inferior angle a minute articular facet for the external cuneiform.

The *external cuneiform* presents on its inner surface an irregular articular facet along its posterior third; this is rather broader above than below, is somewhat constricted about halfway down at its anterior border, and does not usually reach quite to the plantar surface. At the anterior border of the inner surface of this bone there is another articular facet indented at its posterior edge, and marked upon its lower part by a short vertical ridge. All this anterior facet, except the small part behind the small ridge, articulates with the outer side of the base of the second metatarsal bone; the portion behind the ridge is for the facet at the anterior inferior angle of the outer surface of the middle cuneiform. The rest of the inner surface of the external cuneiform is rough and depressed for the interosseous ligament.

The outer surface of this bone is partly articular and partly non-articular; the articular part is smaller than and posterior to the other, and extends the whole depth of the surface; it is broader above than below, where it occupies little more than the posterior inferior angle of this surface, whereas above it extends over fully one-half of it. It is the upper part of this facet which is chiefly in contact with the cuboid; the lower part slides upwards so as to make contact with the facet on the cuboid only when the transverse arch of the foot is contracted.

The *cuboid* presents at the upper part of its inner surface an irregularly triangular-shaped facet, somewhat less than half an inch in diameter, both along its base and from base to apex. It looks inwards and slightly upwards and forwards. The base is at the dorsal aspect, and the apex vertically placed at the junction of the middle and plantar thirds. Between the apex and inferior border is a very deep depression for the cubo-cuneiform interosseous ligament. Behind the facet the bone is rough and depressed, where it gives attachment to the cubo-scaphoid, and in front of the facet it is also rough for the cubo-cuneiform interosseous ligament.

These four bones are arranged so as to form an arch from side to side, the convexity of which looks upwards and outwards. The outer pier of this arch which is formed by the cuboid, descends much lower than the inner which is formed by the internal cuneiform bone. The security of the cuboid is increased by its wedge shape, its base being directed inwards and its narrow end outwards; and by the tubercle of the fifth metatarsal bone projecting backwards over its outer surface.

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between them; that between the posterior facets belonging to the common synovial cavity of the anterior part of the tarsus, that between the upper and anterior belonging to the tarso-metatarsal joints of the second and third bones.

SYNOVIAL CAVITY OF THE ANTERIOR PART OF THE TARSUS.—There is one synovial membrane between the scaphoid and the three cuneiform bones; this sends prolongations forwards between the cuneiform bones and also between the external cuneiform and cuboid, whilst this again sends backwards a short prolongation between the scaphoid and cuboid when these two bones articulate by cartilage-coated surfaces. Usually this synovial membrane extends the whole way between the inner and middle cuneiform bones, and is prolonged into the articulations between them and the second metatarsal bone, as well as into the articulations between the third metatarsal bone and the outer cuneiform, and between the base of the third metatarsal bone and the bases of the second and fourth metatarsal bones.

ARTERIES.—The articulations of the anterior part of the tarsus are supplied by twigs from the metatarsal artery on the dorsum and from the plantar arteries in the sole.

NERVES.—The anterior tibial and the external and internal plantar nerves supply these joints.

MUSCLES CONNECTED WITH THE ANTERIOR PART OF THE TARSUS.—To the *Scaphoid* one muscle is attached, viz., the tibialis posticus, which is inserted into its tuberosity.

To the *Internal Cuneiform*, two muscles, viz., the tibialis posticus and tibialis anticus, which are inserted into its tuberosity.

To the *Middle and External Cuneiform Bones*, two muscles, viz., a slip from the tibialis posticus is sent to each of these bones, and some of the fibres of the flexor brevis pollicis arise from this tendinous slip as it covers them.

With the *Cuboid* three muscles are connected; the tibialis posticus is inserted into it, and the flexor brevis pollicis arises from the inner end of the ridge behind the groove on the plantar surface of the cuboid. The peroneus longus runs along the groove on the external and inferior surfaces of the bone, but is not attached to any part of it.

THE MOVEMENTS OF THE JOINTS OF THE ANTERIOR PART OF THE TARSUS.—These joints are susceptible of only very calcaneo-astragaloid joint, but an opposite effect to that which they have upon the ankle-joint.

Of the muscles which arise from the os calcis, viz., the abductor pollicis, the flexor brevis digitorum, and the abductor minimi digiti, and also the extensor brevis digitorum, all pass over the joint to be inserted into the phalanges, whilst the musculus accessorius is attached to the tendon of the flexor longus digitorum.

The extensors are the tibialis anticus, the extensor proprius pollicis, the extensor longus digitorum, and the peroneus tertius. These muscles also extend the toes, and flex the ankle.

The extensor brevis digitorum extends the foot at the transverse joint, and the toes at the phalangeal, but has no effect upon the ankle.

The flexors are the tibialis posticus, the peroneus longus, the peroneus brevis, the flexor longus pollicis, and the flexor longus digitorum, all of which also extend the foot at the ankle.

The abductor pollicis, abductor minimi digiti, and the flexor brevis digitorum, as well as (indirectly) the musculus accessorius, flex the transverse joint, but cannot act on the ankle.

The Adductors.—The tibialis anticus and posticus draw the toes inwards, and turn the inner border of the sole upwards.

The Abductors.—The peronei draw the toes outwards and turn the outer border of the foot upwards.

In the case of the joints of the foot as of those of the hand, and in fact elsewhere generally, the muscles which pass over several joints act first upon the joint immediately behind its point of insertion, and then in succession upon those which are further and further behind.

THE MOVEMENTS.—The great difference between the movements of the medio-tarsal and tarso-metatarsal joints on the one hand, and of the medio-carpal and carpo-metacarpal joints on the other, is that in the latter the movements are not of a different kind from, though of less extent than those at the wrist, and flexion or extension occurs at all at the same time; whereas in the former movements are more various than at the ankle, and the lateral and rotatory movements are superadded to those of extension and flexion, and flexion at the transverse

made complex by the calcaneo-astragaloid and transverse joints, whilst those at the ankle are simple and limited to flexion and extension.

Flexion and adduction are more free at the transverse joint than extension and abduction, which latter are arrested by the ligaments of the sole as soon as the foot is brought into the position in which it rests on the ground.

Although the astragalo-scaphoid is a ball-and-socket joint, and therefore might allow of movement in any direction, yet the movement at the medio-tarsal joint, owing to the union of the cuboid with the scaphoid, is arrested by the shape of the calcaneo-cuboid joint. The articular surfaces of the latter being concavo-convex from above downwards, prevent rotation round a vertical axis, and also any side-to-side movement except in an oblique direction, downwards and inwards, and upwards and outwards. This is also the direction of the freest movement at the astragalo-scaphoid joint, for the articular facet on the head of the astragalus is most prolonged downwards and inwards, *i.e.*, on the under and inner side.

The ligamentous connexion of the os calcis with the scaphoid also helps to limit the movements of the transverse joint. The lateral movements of the foot, which have often been supposed to take place at the ankle, really occur at the calcaneo-astragaloid and the medio-tarsal joints. Turning the toes out or in, in so far as these movements are not of the tarsal joints, is effected by rotation of the limb at the hip-joint chiefly; but slightly also, when the leg is flexed on the thigh, by rotation of the tibia and fibula at the knee-joint. The twisting movements of the foot, such as turning the sole up on the inner or outer side, and in increasing or diminishing the arch, take place at the tarsal joints, especially at the medio-tarsal and calcaneo-astragaloid joints.

It is also at the medio-tarsal joint that those changes occur, owing to paralysis of some muscles or contraction of others, which result in talipes equinus, varus, or valgus; in the former there is a dropping of the anterior part of the tarsus, and in the other forms a twisting upwards of the inner or outer border of the foot respectively.

The Medio-tarsal or Transverse Tarsal Joint;
or,
The Articulations between the Astragalus and Scaphoid on the inner side, and the Os Calcis and Cuboid on the outer side of the Foot.

What is often spoken of as the articulation of the anterior and posterior portions of the tarsus with one another, under the name of the medio-tarsal or transverse tarsal joint, is in reality two articulations, each of which is separate and distinct from the other. These two joints are, however, in the same transverse line, and the movements of the anterior portion of the foot upon the posterior take place at both of them simultaneously. The two anterior bones, viz., the scaphoid and cuboid, are united together by means of dorsal, plantar, and interosseous ligaments; and, as has been stated above, sometimes each bone is marked by a small articular facet when the outer extremity of the former is in contact with the inner surface of the cuboid.

The two posterior bones are united in the manner which has been fully described above, and form between them two important articulations, the anterior of which is in communication with the astragalo-scaphoid portion of the transverse tarsal joint, and the movements of both are in intimate relationship with those of the transverse tarsal joint. It will be most convenient to consider the two parts of this joint separately so far as regards their bones and ligaments, under the heads of the astragalo-scaphoid and the calcaneo-cuboid articulations, and afterwards to enumerate the muscles and describe the movements which are common to them both.

The Astragalo-scaphoid Articulation.

Class, Diarthrosis. *Subdivision*, Enarthrodia.

This is the only ball-and-socket joint in the tarsus. It is not complete in itself, being in communication with the anterior calcaneo-astragaloid joint, and two of the ligaments which assist in closing it in are not attached to the astragalus at all, but pass from the os calcis to the scaphoid.

THE ASTRAGALUS.—The articular surface of the *head of the astragalus* is situated one inch in front of the anterior edge of the facet on the upper surface of the bone for the tibia, being

LIGAMENTS.—The first metatarsal bone is connected with the internal cuneiform by a complete capsular ligament, the fibres of which are very thick on the under and inner aspects. Those on the outer side pass from behind forwards in the interval between the interosseous ligaments which connect these two bones with the second metatarsal bone. The plantar ligament is by far the strongest, and at the cuneiform bone it is blended with the inferior scapho-cuneiform ligament.

SYNOVIAL MEMBRANE.—This articulation is completely separated from, and on a line anterior to, all the other tarso-metatarsal joints.

The Middle Tarso-metatarsal Articulation.

Into this part of the union of the tarsus with the metatarsus there enter the three cuneiform, and the second and third metatarsal bones.

The *outer surface of the internal cuneiform bone* presents at the anterior part of its upper border a small elongated facet for the inner surface of the base of the second metatarsal bone, which is continuous with, but marked off by a slight vertical ridge from the facet for the middle cuneiform bone. The rest of the outer surface of this bone, where it faces the second metatarsal, is rough for the attachment of ligaments.

The *anterior surface of the middle cuneiform bone* receives upon it the terminal facet at the base of the second metatarsal bone. It is flat, somewhat triangular in shape, with its base at the dorsum and its rounded apex at the plantar aspect. It is about three-quarters of an inch in vertical measurement, and about half an inch across at the dorsum, but much narrower below.

The *outer cuneiform bone* enters into this articulation (1) by its anterior surface, which is of the same size and character as that of the middle bone, and articulates with the terminal facet on the base of the third metatarsal bone; and (2) by the anterior edge of its inner surface, which presents two small facets, separated by a rough interval, which look a little forwards as well as inwards to articulate with the posterior two facets on the outer side of the base of the second metatarsal bone. Sometimes these facets are continuous with each other, like those on the second metatarsal bone.

The *inferior calcaneo-scaphoid* is an exceedingly dense and thick plate of fibrous tissue. It extends from the sustentaculum tali and from the under surface of the os calcis in front of a ridge curving outwards from that process to the anterior tubercle, to the whole width of the under surface of the scaphoid near its posterior border, and to the inner surface of the scaphoid behind the tubercle. Internally, the ligament is blended with the anterior portion of the internal lateral ligament of the ankle-joint, and externally with the lower border of the external calcaneo-scaphoid ligament.

The thickest portion of the ligament is that along the inner border of the sole, which passes to the scaphoid behind the tubercle. At this part the ligament loses the well-marked fibrous appearance which it has in the sole of the foot, and becomes smooth and facetted; and over it here the tendon of the tibialis posticus passes into the sole of the foot, giving considerable support to the head of the astragalus, and assisting the power and spring of the ligament. Moreover, by coming into action when the heel is raised, it helps the ligament to support the head of the astragalus, and to maintain the arch of the foot when the weight of the body is thrown forward upon the instep. Besides supporting the head of the astragalus, and providing a smooth surface upon which the under part of the head of the astragalus moves, this ligament also limits the movements of the scaphoid on the astragalus.

The direction of the fibres of the ligament being inwards as well as forwards, they are kept tight in flexion as well as in extension of the sole of the foot; for the rotation inwards which accompanies flexion prevents the approximation of the under surface of the scaphoid to the os calcis which would otherwise result from flexion; and the approximation of the under surfaces of these bones which would otherwise arise during the rotation outwards which accompanies extension, is obviated by the separation caused by the extension movement itself. Flat foot is a consequence of the weakening of this ligament, for then the head of the astragalus is pressed forwards and inwards, and over-extension and rotation outwards of the forepart of the foot results.

The *astragalo-scaphoid ligament* is a broad, thin, but well-marked layer of fibres, attached to the dorsal and external surfaces of the neck of the astragalus, and all along the dorsal surface of the scaphoid. Many of the fibres converge to their insertion on the scaphoid. The fibres low down on the outer side blend a little way from their origin from the neck of the astragalus with the upper part of the external calcaneo-scaphoid ligament, and then pass forwards and inwards to the scaphoid; those next above pass obliquely, and with a distinct twist in their course, over the outer and upper side of the head of the astragalus to the centre of the dorsum of the scaphoid. These latter overlap some fibres which incline outwards from the inner side of the astragalus, as well as others which are prolonged onwards from the anterior ligament of the ankle-joint.

THE SYNOVIAL MEMBRANE.—The same synovial membrane which lines the anterior calcaneo-astragaloid articulation lines also the astragalo-scaphoid joint.

Calcaneo-cuboid Articulation.

Class, Diarthrosis. *Subdivision*, Arthrodia.

This joint forms the outer portion of the medio-tarsal articulation, and from its construction is susceptible of less movement than the inner portion, viz., the astragalo-scaphoid.

THE OS CALCIS.—The anterior surface of the os calcis presents a concavo-convex facet for the posterior surface of the cuboid bone, the concavity being from above downwards and inwards. This facet measures about three-quarters of an inch from above downwards, and about one inch from side to side. Its inferior border is nearly straight but slightly arched upward, whilst its lateral and superior borders form almost the half of a circle. It is depressed from above downwards, near its inner end, to receive the convexity of the cuboid, and the articular surface is prolonged onwards somewhat upon the plantar surface of the bone, to articulate with the posterior internal and inferior angle of the cuboid, which looks upwards and projects backwards beneath it, whilst the superior internal angle of the os calcis projects forwards so as to overhang the inferior internal angle of the cuboid. A small but elongated part of this anterior surface of the os calcis, towards its upper and inner side, is non-articular, for the attachment of the external calcaneo-scaphoid and the internal calcaneo-cuboid ligaments. The anterior facet of the os calcis for the astragalus is situated upon the upper surface of this overhanging corner of the bone, and the anterior edge of this facet is separated from the facet for the cuboid by only a very narrow strip of bone, to which the internal calcaneo-cuboid ligament is attached.

THE CUBOID.—The posterior surface of the cuboid, which faces a little outwards, is occupied by an irregularly shaped facet for articulation with the os calcis. It measures about an inch from side to side, three-quarters of an inch from above downwards at the inner end, and about three-eighths of an inch at the outer end. Its upper and lower margins are arched from side to side with their convexity upwards, and its inferior and internal angle is prolonged backwards beneath the overhanging upper and inner angle of the os calcis. It is obliquely convex from above downwards and inwards, in adaptation to the concavity of the anterior surface of the os calcis.

LIGAMENTS.—The ligaments connecting these bones are the long and short plantar or inferior calcaneo-cuboid ligaments, together with the internal and the dorsal calcaneo-cuboid ligaments.

The *internal or interosseous calcaneo-cuboid ligament* is attached to the inner and slightly also to the under part of the anterior surface of the os calcis, close to the margin of the articular facet of the cuboid, and it passes forwards to be attached to the rough internal posterior and inferior angle, and also to the depression of the internal surface of the cuboid. It is closely connected at the os calcis with the external calcaneo-scaphoid ligament. Towards the sole it is connected with the deep or short inferior calcaneo-cuboid ligament, and superiorly with the dorsal calcaneo-cuboid ligament.

The *dorsal calcaneo-cuboid ligament* is attached to the dorsal surfaces of the two bones and extends low down upon their sides towards the sole, so as to blend with the short inferior calcaneo-cuboid ligament. Over the inner half or more the ligament stretches some distance beyond the margins of the articular surfaces, and reaches well forwards upon the cuboid so as to be attached about midway between its anterior and posterior borders; but towards the outer side the ligament is much shorter, and is attached to the cuboid behind its tubercle.

The *inferior calcaneo-cuboid ligaments*, or the long and the short plantar ligaments, are two very strong bands which pass between the under surface of the os calcis and cuboid. They are separated by a slight interval occupied by fatty and areolar tissue, where the long overlaps the small ligament.

The *long ligament* is attached behind to the whole of the under surface of the calcaneum between the posterior tubercles and the anterior tubercle. Most of its fibres pass directly forwards, and are fixed to the outer two-thirds or more of the oblique ridge, behind the peroneal groove on the cuboid bone; while some of the fibres pass still further forwards and inwards, expand into a broad layer, and are inserted into the bases of the second, third, and fourth, and inner half of the base of the fifth metatarsal bones. This anterior expanded portion completes the canal for the peroneus longus tendon, and from its under or plantar aspect there arise the adductor pollicis and the flexor brevis minimi digiti muscles.

The *short plantar ligament* is attached posteriorly to the anterior tubercle of the calcaneum and to the bone immediately in front of this; it then takes an oblique course forwards and inwards, and is attached to the whole of the depressed triangular inferior surface of the cuboid behind the oblique ridge, except its outer angle. From the plantar aspect of this ligament the flexor brevis pollicis in part arises. This ligament connects the contiguous edges of the os calcis and the cuboid, and therefore its upper surface is to some extent lined by the synovial membrane of the calcaneo-cuboid joint. It is strongest near the outer edge of the foot.

The long and short plantar ligaments limit extension at the medio-tarsal joint, *i.e.*, of the second row of the tarsal bones upon the first; they are also the chief support of the outer part of the antero-posterior arch of the foot, and indeed the long ligament seems intended to strengthen the rest of the arch also.

They are sometimes unnaturally contracted and give rise to a deformed arching of the foot, commonly called by surgical writers talipes plantaris, which is an abnormal and permanent flexion of the foot at the medio-tarsal joint.

It should be noticed that all the ligaments which connect the posterior with the anterior segments of the tarsus are attached behind to the os calcis, with the exception of one, viz., the superior astragalo-scaphoid. Thus besides the internal, dorsal, and inferior calcaneo-cuboid ligaments, there are also the inferior and external calcaneo-scaphoid ligaments; so that the os calcis which forms with the cuboid a far less movable articulation than the astragalus forms with the scaphoid, is yet held to and united with the scaphoid, though it is not in contact with it; and in this way the two portions of the medio-tarsal joints are held together and are made to move as if they formed but one articulation.

THE SYNOVIAL MEMBRANE.—The calcaneo-cuboid articulation has a synovial lining distinct from that of any other joint in the tarsus. It is less capacious than that which belongs to the astragalo-scaphoid articulation.

THE ARTERIES OF THE MEDIO-TARSAL JOINT.—1. The anterior tibial sends a branch over the inner border of the foot, which furnishes twigs to the astragalo-scaphoid joint. 2. The tarsal artery sends forwards branches which anastomose with recurrent branches of the (3) metatarsal artery. 4. The plantar arteries, but most frequently the internal plantar, supply the articulations on the under aspect.

THE NERVES OF THE MEDIO-TARSAL JOINT.—Branches are supplied to the astragalo-scaphoid and calcaneo-cuboid joints from the external branch of the anterior tibial, and occasionally from the musculo-cutaneous or the external plantar.

THE MUSCLES IN RELATION WITH THE MEDIO-TARSAL JOINT.—The muscles which act upon the medio-tarsal joint either arise from the bones of the leg and move the foot at the ankle, and the os calcis with the foot upon the astragalus, as well as the transverse joint; or, they arise from the os calcis and are inserted into the phalanges of the toes. Of the nine muscles which arise in the leg and pass over the medio-tarsal joint to their insertion, three, viz., the peroneus longus, the peroneus brevis, and the peroneus tertius, are attached to the bases of the metatarsal bones; one, viz., the tibialis anticus, is inserted into the internal cuneiform and the base of first metatarsal bone; and one, the tibialis posticus, spreads out so as to be attached to all the bones of the anterior part of the tarsus, as well as to the bases of the second, third, fourth, and part of the fifth metatarsal bones; whilst in addition a slip passes backwards also to the sustentaculum tali.

Most of these muscles produce upon this joint an increased degree of the same action as that which they excite upon the calcaneo-astragaloid joint, but an opposite effect to that whic they have upon the ankle-joint.

Of the muscles which arise from the os calcis, viz., th abductor pollicis, the flexor brevis digitorum, and the abduct minimi digiti, and also the extensor brevis digitorum, all pa over the joint to be inserted into the phalanges, whilst th musculus accessorius is attached to the tendon of the flex longus digitorum.

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THE MOVEMENTS.—The great difference between the movements of the medio-tarsal and tarso-metatarsal joints on th one hand, and of the medio-carpal and carpo-metacarpal joint on the other, is that in the latter the movements are not of different kind from, though of less extent than those at th wrist, and flexion or extension occurs at all at the same time whereas in the former movements are more various than at th ankle, and the lateral and rotatory movements are superadde to those of extension and flexion, and flexion at the transvers joint of the foot is simultaneous with extension at the ankle-joint, and *vice versâ.*

Flexion and extension at the medio-tarsal joints are not movements consisting merely of turning upon a transverse axis. The direction of movement is regulated by the articular surface of the head of the astragalus, and the axis of movement is oblique from within outwards, and somewhat backwards and downwards through the astragalus and os calcis.

Combined with flexion and extension are also some rotatory movements round an antero-posterior axis, and a fair amount of lateral movement, whereby the anterior part of the foot can be inclined inwards or outwards. Thus flexion is associated with inward rotation of the sole, together with inclination inwards of the toes; and extension with rotation outwards of the sole, together with outward inclination of the toes.

These movements of the transverse joint occur, as has been stated, in conjunction with movements of the calcaneo-astragaloid and ankle-joint. Rotation at the calcaneo-astragaloid joints differs in direction and in effect from rotation at the medio-tarsal joint. At the former it occurs in a nearly horizontal plane round a vertical axis; at the latter, round an antero-posterior axis, in a nearly vertical plane. As regards the results of rotation at the two joints, rotation at the calcaneo-astragaloid turns the toes inwards or outwards, whilst at the transverse joint it turns the inner or the outer edge of the foot upwards. Again, the gliding movements of the calcaneo-astragaloid joints have the effect of elevating or depressing the edge of the foot, whilst those of the transverse tarsal joint cause the toes to turn towards or away from the middle line of the body without altering the position of the os calcis with respect to the astragalus.

Flexion at the medio-tarsal joint is associated with adduction and inward rotation of the foot, which occurs simultaneously with extension of the ankle; and extension at this joint, which is associated with abduction and rotation outwards, occurs simultaneously with flexion of the ankle.

Thus we find in the foot that the movements of the ankle and tarsus are intimately associated, as are those of the hand at the wrist and carpus; but whilst those in the hand are simple, and those about the wrist are made complex by the rolling of the radius upon the ulna; the movements of the foot are made complex by the calcaneo-astragaloid and transverse joint whilst those at the ankle are simple and limited to flexion an extension.

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The Tarso-metatarsal Articulations.

Class, Diarthrosis. *Subdivision*, Arthrodia.

There may be said to be three separate joints between the tarsus and metatarsus; 1st, the articulation between the internal cuneiform and the first metatarsal bone; 2nd, the articulation between the three cuneiform and the second and third metatarsal bones; and 3rd, the cubo-metatarsal, or the joint between the cuboid and the fourth and fifth metatarsal bones. Looked at as a whole, the union of the tarsus with the metatarsus is very uneven, owing to the backward projection of the second, fourth, and fifth bones behind the line of the third; and of the forward position of the first, which articulates with the inner cuneiform nearly half an inch in advance of the second, and about a quarter of an inch in front of the third metatarsal bone, where they articulate with the middle and outer cuneiform bones respectively.

The second metatarsal bone is supported by the middle cuneiform, and is let back into a space bounded on the outer and inner sides by the external and internal cuneiform bones. The outer three metatarsal bones are placed pretty evenly, in a line having a gentle curve with its convexity towards the phalanges.

We will consider first the internal, next the middle, and lastly the outer or cubo-metatarsal joints.

The Inner Tarso-metatarsal Joint.

THE BONES.—The *anterior surface of the internal cuneiform bone* is entirely occupied by a large, nearly flat, kidney-shaped articular surface, which is inclined a little inwards. It is placed with its long axis vertically, its convex border inwards, and its concave border outwards. It measures an inch from above downwards, and half an inch from side to side.

The *tarsal surface of the base of the first metatarsal bone* is slightly concave from side to side. It is of the same general shape as the anterior surface of the inner cuneiform, which it accurately fits. At its outer side, where the border of the facet is concave, this surface presents an elongated, rough, shallow groove for the attachment of a ligament, and in front of it, but situated upon the outer surface of the base, is the facet for the second metatarsal bone when present.

The *second and third metatarsal bones* present at their tarsal extremities facets which correspond in shape and size with the facets on the anterior surfaces of the middle and outer cuneiform bones. The second bone also presents on its outer surface two small facets, which look outwards and backwards, for the inner surface of the outer cuneiform. These are continuous over a small margin with the facet for the middle cuneiform bone, and over slight vertical ridges with the facets for the inner side of the third metatarsal bone.

THE LIGAMENTS.—Dorsal, plantar, and interosseous ligaments connect the cuneiform bones with the metatarsus, and serve to enclose this middle part of the tarso-metatarsal joint.

The Dorsal Ligaments.—Some fibres pass between the inner cuneiform bone and the second metatarsal bone. These short fibres cross obliquely from the outer edge of the cuneiform to the inner border of the base of the metatarsal bone; they take the place of a dorsal metatarsal ligament which is wanting between the first and second metatarsal bones.

Between the middle cuneiform bone and the base of the second metatarsal bone some fibres run directly forwards.

Between the external cuneiform and (1) the outer corner of the second metatarsal bone a narrow band is directed obliquely inwards; (2) another short band passes obliquely outwards from the outer cuneiform to the inner edge of the base of the fourth metatarsal bone; and (3) between these two sets of oblique fibres others run directly forwards from the cuneiform to the third metatarsal bone.

The Plantar Ligaments.—A strong ligament passes between the inner cuneiform and the bases of the second and third metatarsal bones. The tibialis posticus is inserted into these bones close to it. Other slender ligaments connect the middle cuneiform with the second, and the outer cuneiform with the third metatarsal bones.

Interosseous Ligaments.—The middle portion of the tarso-metatarsal joint is shut off from the inner portion by a very strong and broad interosseous ligament, which extends between the outer surface of the first cuneiform and the inner surface of the base of the second metatarsal bone; to both bones it is attached below and in front of the articular facets.

The second band is attached behind to a fossa on the anterior and external edge of the external cuneiform, and to

securely fixed in its proper place between the os calcis and metatarsus.

THE LIGAMENTS.—Ligaments connect the cuboid with the fourth and fifth bones on all sides.

The *plantar cubo-metatarsal ligament* is a broad, but well-marked ligament, which extends from the cuboid behind to the bases of the metatarsal bones in front. It is by no means a thick ligament, and to see it the long plantar ligament, the peroneus longus, and the external slip of the tibialis posticus must be removed. The attachment of these structures to the fourth and fifth metatarsal bones assists their union with the tarsus very considerably. This ligament is continuous along the groove at the base of the fifth metatarsal bone with the dorsal ligament; as it passes round the outer border of the foot it is somewhat thickened, and may be described as the *external cubo-metatarsal ligament.* On the inner side it joins the interosseous ligament connecting the cuboid and external cuneiform behind, with the third and fourth metatarsal bones in front, and thus completes on the under side a well-formed capsular ligament for the cubo-metatarsal joint, as the interosseous ligament itself completes it on the inner side.

The Dorsal Cubo-metatarsal Ligament.—On the dorsal aspect, ligamentous fibres pass obliquely forwards and outwards from the cuboid to the bases of the fourth and fifth metatarsal bones, and cover in the synovial membrane above; those which are attached to the latter reach outwards to the tuberosity and are very oblique; they are continuous on the outer side with what has just been referred to as the external cubo-metatarsal ligament.

The *interosseous ligament* shuts off this joint from the middle tarso-metatarsal joint. It is attached to the external cuneiform behind, and to the whole depth of the posterior and inner angle of the base of the fourth metatarsal bone, and to the apposed sides of the fourth and third metatarsal bones towards the plantar surface.

SYNOVIAL MEMBRANE.—The synovial membrane of this joint is shut off from the rest of the tarsal and tarso-metatarsal joints, but sends a prolongation forwards to the inter-metatarsal articulation between the fourth and fifth metatarsal bones. The septum between the cubo-metatarsal and the middle tarso-metatarsal joints is very seldom absent.

ARTERIES OF THE TARSO-METATARSAL ARTICULATIONS.—To the joint of the great toe on the dorsal aspect, one or two branches are given off from the inner side of the dorsalis pedis before it divides in the first interosseous space. On the plantar aspect of this joint twigs are supplied from the internal plantar artery.

The metatarsal artery which usually crosses the proximal end of the shafts of the four outer metatarsal bones supplies the corresponding joints by twigs given off from the under side of the recurrent branches which anastomose with the tarsal artery. On the plantar surface branches are given to these joints from the deep plantar arch.

NERVES.—Branches are supplied from the anterior tibial and the plantar nerves.

THE MUSCLES CONNECTED WITH THE TARSO-METATARSAL ARTICULATIONS.—Of the muscles in relation with these joints, some arise in the leg and pass over the foot to be inserted into the metatarsal bones, and others into the phalanges; and some arise from the tarsus, and are inserted into the phalanges. Other muscles arise from the metatarsal bones themselves, and are inserted into the phalanges; but they do not act on this joint, and will be best considered under the head of the metatarso-phalangeal joints.

The *muscles which arise in the leg and are inserted into the metatarsus* are: (1) the three peroneal muscles; (2) the tibialis anticus and posticus, both of which are in part inserted into the tarsus and in part into the metatarsus; and (3) the extensor ossis metatarsi pollicis, which occasionally is present either as a distinct muscle or as a slip from one of the long extensors.

The *muscles which arise in the leg and are inserted into the phalanges*, are the extensor proprius pollicis, and when present the extensor primi internodii pollicis, which is generally an offshoot of the extensor proprius pollicis; the flexor longus pollicis, and the flexor longus digitorum. All of these are inserted into the terminal phalanges of their respective toes. The extensor longus digitorum, which (after blending with the extensor brevis digitorum) is inserted into the second and third phalanges.

The *muscles which arise in the tarsus and are inserted into the phalanges*, are the extensor brevis digitorum, which arises from the outer surface of the os calcis and from the lower band of the anterior annular ligament, to be inserted by four slips, one into the dorsal surface of the first phalanx of the great toe, and the other three with slips of the extensor longus digitorum into the bases of the second and third phalanges of the second, third, and fourth toes. The flexor accessorius, which arises by two heads from the os calcis and long plantar ligament, and is inserted into the external border and upper and lower surfaces of the flexor longus digitorum; it thus acts primarily with that muscle on the terminal phalanges of the four outer toes. The abductor pollicis, which is inserted with the inner head of the flexor brevis pollicis into the inner side of the base of the first phalanx of the great toe. The abductor minimi digiti, which is inserted into the external surface of the base of the first phalanx of the fifth toe. The flexor brevis digitorum, which is inserted into the second phalanx of each of the four outer toes by slender tendons, which divide so as to allow of the tendon of the flexor longus digitorum passing between them on its way to the terminal phalanges of the same toes. All these arise from the under surface of the os calcis. The flexor brevis pollicis arises from the os cuboides and from the tendon of the tibialis posticus, where it is attached to the cuneiform bones; it divides into two muscular bellies, each of which ends in a tendon, one to be inserted into the inner and the other into the outer side of the base of the first phalanx of the great toe, as well as into the sesamoid bones on its own side of the metatarso-phalangeal joint. The adductor pollicis arises from the sheath of the peroneus longus, as well as from the bases of the third and fourth metatarsal bones, and is inserted with the outer head of the flexor brevis pollicis into the outer side of the base of the first phalanx of the great toe. The flexor brevis minimi digiti arises from the sheath of the peroneus longus, as well as from the base of the fifth metatarsal bone, and its tendon is inserted into the base and outer border of the first phalanx of the fifth toe.

One muscle occasionally exists, which arises from the external tubercle of the os calcis, and is inserted into the tubercle of the base of the fifth metatarsal bone beneath the plantar fascia, viz., the abductor ossis metatarsi minimi digiti.

The muscles which are inserted into the phalanges act *first* upon the phalangeal and metatarso-phalangeal articulations, and *secondarily*, when their action on the two former has been completed or prevented, upon the tarso-metatarsal joints, as

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The Inter-metatarsal Articulations.

Class, Diarthrosis. *Subdivision*, Arthrodia.

THE BONES.—The base of each of the metatarsal bones is wedge-shaped, except that of the fourth, which is cuboidal, and each presents a terminal facet for articulation with the tarsus, and one or more lateral facets for articulation with one another; but in this respect they differ somewhat from one another.

The *base of the first metatarsal bone*, as a rule, presents no lateral articular facet; but I have seen occasionally a small facetted surface at the centre of the concave border of the base of this bone to articulate with the inner surface of the base of the second bone. The inferior and external angle of the base projects slightly outwards, and is marked by a rough circular depression, to which the peroneus longus is attached.

The *base of the second metatarsal bone* has upon its inner side near the dorsum a small, nearly square facet, continuous with the facet at the tarsal extremity of the bone, for the outer surface of the inner cuneiform bone. Occasionally there exists below and in front of this another, but smaller and much less marked, facet for the outer surface of the base of the first metatarsal bone. Whilst the lateral facet on the first metatarsal bone, when present, is close to the terminal facet for the inner cuneiform, that on the inner surface of the second bone is on the side of the shaft immediately in front of the base, and rather nearer the plantar than the dorsal aspect. Upon its outer surface are two facets, separated by a deep narrow antero-posterior groove, to which an interosseous ligament is attached, and each of these facets is divided into two unequal parts by a vertical ridge; the parts behind the ridges look outwards and backwards, are smaller than those in front, and articulate with the inner surface of the external cuneiform bone; and the parts in front of the ridges look outwards and forwards, and articulate with the inner surface of the third metatarsal bone.

The *base of the third metatarsal bone* presents on its inner aspect two articular facets, separated by an antero-posterior depression; the upper one is smaller than the lower; both are continuous with the terminal facet. On its outer side is a large circular facet, occupying half the vertical depth of the surface, the margin of which extends up to the dorsal and back to the terminal surfaces of the bone. Below the facet is a rough and irregular depression for the interosseous ligament.

The *base of the fourth metatarsal bone* presents along the dorsal half of the inner surface an elongated facet five-eighths of an inch in the antero-posterior direction, *i.e.*, from the tarsal surface towards the shaft, which is divided by a vertical ridge into two parts of nearly equal size, that behind, which is somewhat the smaller, being for the outer surface of the outer cuneiform bone, and that in front being for the outer surface of the base of the third metatarsal bone. The ridge which divides this facet into two parts, like the corresponding ridges on the outer side of the base of the second bone, is coated by articular cartilage; and thus we see that the synovial cavity between these bones and the tarsus is continuous, and indeed is one with the synovial cavity between the bones and the third metatarsal bone. On the outer side of the base of this bone is a triangular slightly concave articular facet for the fifth bone; its base is at the dorsal aspect, its apex near the plantar surface at the tarsal edge, and its anterior margin, which is convex in front, is separated from the bone in front by a deep sulcus which runs downwards and backwards for the interosseous ligament. This facet is rather overhung by the dorsal surface of the base.

The *base of the fifth metatarsal bone* presents on its inner aspect a large irregularly triangular facet, the base of which is the smooth facetted but angular border which separates this lateral surface for the fourth bone from the terminal facet for the cuboid. The outer surface of this bone is prolonged backwards into a rough tubercle, to which is attached the peroneus brevis muscle.

THE LIGAMENTS.—The bases of the metatarsal bones are connected together firmly by three sets of ligaments, which hold their facetted surfaces in apposition. At their proximal ends these bones are loosely united by transverse ligaments. Between the bases of the first and second bones there are a few interosseous bands chiefly situated towards the plantar aspect. The place of a dorsal ligament between these two bones is occupied by the ligament which extends from the inner cuneiform bone to the second metatarsal. When these two bones are in articular contact the facets are surrounded by some short fibrous tissue.

Dorsal Ligaments.— Broad membranous ligaments pass between the contiguous bones of the four outer toes on their dorsal aspect.

Plantar Ligaments.—Strong, thick, well-marked ligaments similarly connect them on the plantar aspect.

Interosseous Ligaments.—Three very strong interosseous ligaments connect the same bones, and fill up the (often deep) sulci on their sides. They are situated at the point of union of the shafts and bases of the bones, so as to limit the synovial cavities in front of the lateral facets.

SYNOVIAL MEMBRANE.—The common synovial membrane of the tarsus extends between the bases of the second and third and third and fourth bones. The synovial membrane of the cubo-metatarsal joint extends between the fourth and fifth bones.

ARTERIES OF THE INTER-METATARSAL JOINT.—On the dorsal aspect the metatarsal artery, and on the plantar surface, the deep plantar arch supply these joints.

NERVES.—The anterior tibial and the plantar nerves supply twigs to these as well as to the tarso-metatarsal joints.

THE MUSCLES CONNECTED WITH THE METATARSAL BONES, are either inserted into them or arise from the sides of their shafts, and pass to be inserted into the phalanges. The *peroneus longus,* which is inserted into the outer side of the base of the first bone on its plantar aspect; and the *tibialis posticus,* which is inserted into the plantar surface of the base of the second, third, fourth, and fifth bones, require to be especially mentioned, because by their action they tend to keep up the transverse arch formed by the metatarsal bones. The *peroneus tertius* and *peroneus brevis,* and the occasional muscle, viz., *the abductor ossis metatarsi minimi digiti,* are attached to the tuberosity of the fifth bone, and tend to draw it away from the side of the fourth bone whilst they abduct it upon the cuboid. The peronei have this tendency, and at the same time they raise the outer side of the foot. The *tibialis anticus* is attached to the inner and lower part of the base of the first metatarsal bone, and in its action of raising the inner border of the foot it tends to draw the first bone from the second.

The *abductor minimi digiti* slides along a smooth impression on the plantar surface of the base of the fifth bone, but is not attached to it.

The other muscles which are connected with the metatarsal bones act on the metatarso-phalangeal and phalangeal joints, and will be enumerated under the former.

THE MOVEMENTS at the inter-metatarsal joints consist only of a gliding of the one upon the other, for the purpose of increasing the depth of their transverse arch, or of diminishing the depth so as to allow of the widening of the foot by the spreading out of the bones. When the arch is increased the outer and inner bones slide downwards upon the fourth and second, and the third rises upwards between the last two, whilst they are all drawn nearer together on their plantar aspect. When the anterior part of the foot is flattened out the third bone descends, whilst the outer and inner rise a little upon the fourth and second.

Considerable flexibility and elasticity is given to the anterior part of the foot by these joints, enabling it to become moulded to the irregularities of the ground on which it rests.

The Connexion of the Heads of the Metatarsal Bones.

The heads of the metatarsal bones are connected together on their plantar aspect by what is called the *transverse ligament.* This consists of four bands of fibres which pass in a transverse direction from bone to bone, like those at the head of the metacarpal bones, with this exception, that a band extends to the head of the metatarsal bone of the great toe, whilst the ligament in the hand does not extend to the metacarpal bone of the thumb. They limit the distance to which the metatarsal bones can be separated in bearing the weight of the body. They are blended with the lateral borders of the fibro-cartilaginous plates of the metatarso-phalangeal joints, and with the sheaths of the flexor tendons where they are connected with the fibro-cartilages.

The metatarsal bones form a considerable part of the foot. The metatarsus is square in shape, of about two inches and a half in diameter, with four interosseous spaces between the bones. It presents a convexity upon the dorsal aspect, both longitudinally and transversely. It is rather wider in front than behind. Its inner border is thick and straight, and is formed by the first metatarsal bone; its external border formed by the fifth metatarsal bone is thinner and concave; its anterior limit is the line of the metatarso-phalangeal joints, and is convex; the posterior is rendered uneven by the line of the tarso-metatarsal joints.

The Metatarso-phalangeal Articulations of the four Outer Toes.

Class, Diarthrosis. *Subdivision*, Ginglymus.

These joints resemble the metacarpo-phalangeal. The concave articular surface of the posterior extremity of each proximal phalanx is adapted to the head of the metatarsal bone. A separate synovial membrane belongs to each joint.

THE BONES.—The *anterior or digital extremity of each metatarsal bone* presents a rounded articular head, which is more pronounced and projecting on the plantar surface, upon which aspect the facet is prolonged furthest to allow of the greater freedom of flexion than of extension; it is flattened upon the sides. On each side of the head, behind the articular surface, is a depression or groove, and behind the groove a ridge or tubercle, to which the lateral ligament of the joint is attached.

The *proximal extremity of the metatarsal phalanx* of each toe forms a concave facet for the rounded head of the metatarsal bone. This facet is very shallow, but is deepened in the recent state by the fibro-cartilaginous plate connected with its plantar margin. Its transverse diameter is greater than the dorso-plantar, the reverse of the shape of the head of the metacarpal bone, which is extensive from before backwards, but compressed from side to side.

THE LIGAMENTS.—The chief of these are the lateral ligaments, but the synovial sac is everywhere covered in by ligamentous, and tendinous, or cartilaginous structures.

The Lateral Ligaments.—Two lateral ligaments, one on each side, maintain the bones in apposition. Each passes from the ridge on the side of the head of the metatarsal bone to the side of the proximal end of the first phalanx, and to the side of the sesamoid body. On the plantar side they are connected together by the sesamoid or fibro-cartilaginous plate; on the dorsal aspect, by short ligamentous fibres, which extend across the ends of the bones and are connected with the under surface of the extensor tendons.

Plantar Fibro-cartilaginous Plate.—This, like the corresponding structure, sometimes called the *glenoid ligament*, in the fingers, helps to deepen the shallow facet of the phalanx for the head of the metatarsal bone. It is more firmly connected with the phalanx than with the metatarsal bone, to which latter it is held by some loose areolar tissue. Laterally, it is connected with the lateral ligaments and with the bands of the intertransverse ligament, which unites the heads of the metatarsal bones. Like the sesamoid bones of the great toe, and the fibrous tissue which connects. them, the cartilaginous plates of the other toes serve to prevent dorsal dislocation of the phalanx. This plate is grooved inferiorly, where it forms a part of the sheath of the flexor tendons.

The Dorsal or Superior Ligament.—On the dorsal aspect the joint is covered in by the expansion of the extensor tendons, and by some loose fine fibres of areolo-fibrous tissue, which extend across the bones to which they are connected, so as to form with the lateral ligaments and the plantar cartilage a capsular investment. These dorsal ligaments assist in holding the extensor tendons down to the bones.

The SYNOVIAL MEMBRANE forms a loose capacious sac, which is protected on the sides by the lateral ligaments; beneath, by the fibro-cartilaginous plate, and by some loose cellular tissue attaching the plate to the plantar surface of the metatarsal bone; and above, by the dorsal or superior ligament.

ARTERIES.—Little branches of the digital and interosseous arteries penetrate the ligaments, and supply the synovial membrane. The joint of the second toe derives twigs from the dorsal artery of the great toe, and from the plantar branch of the dorsal artery of the foot to the first interosseous space.

NERVES.—Twigs are derived from the cutaneous digital branches, or from the small branches for the interosseous muscles.

MUSCLES.—The muscles in connexion with the metatarso-phalangeal joint, are (1) the superficial and deep flexors, which pass over the smooth surface of the fibro-cartilaginous plate on the plantar surface of the joint, and the sheath of which is attached to the margins of the plate, and to the lateral and transverse ligaments where they meet together. (2) The plantar and dorsal interosseous muscles which arise from the metatarsal bones pass above the transverse ligament, and are inserted partly into the side of the base of the first phalanx, and partly into the expansion of the extensor tendon. (3) The lumbrical muscles, which pass below the transverse ligament, and are inserted into the inner side of the extensor tendon over the base of the metatarsal phalanx. (4) The tendons of the extensor muscles. (5) The transversus pedis arises from the inner side of the joints of the four outer toes.

Flexion is performed by the flexor longus digitorum, flexor brevis digitorum, flexor accessorius, the interossei, and the lumbricales; and in the case of the little toe by the flexor brevis minimi digiti.

Extension by the extensor longus digitorum, and, except in the case of the little toe, by the extensor brevis digitorum.

Abduction, which has reference to the middle line of the second toe, is performed by the dorsal interossei, two of which abduct the second toe, one the fourth toe, and one the third toe. The abductor minimi digiti acts on the little toe.

Adduction is effected by the three plantar interossei which act on the middle, fourth, and fifth toes; and by the transversus pedis which act on these same toes through their connexion with the internal lateral ligaments of the joints, as well as on the great toe through its insertion into the base of the first phalanx.

The four lumbricales and the seven interossei muscles have each a double action, for while they bend the first phalanx on the metatarsal bone they extend the second and third phalanges on the first and second. The lumbricales do this by passing over the plantar surface of the transverse ligament to their insertion into the extensor tendon; and the interossei, by having some fibres of their tendons inserted directly into the sides of the base of the phalanx itself, which therefore act directly upon it; whilst others blend with the extensor tendon, and thus act on the second and third phalanges indirectly through their connexion with it.

The muscles which act on these joints give a powerful support to the antero-posterior arch of the foot; and the muscles which arise from the hinder part of the os calcis, by arising also in part from the plantar fascia, make that structure tense, by preserving its curve (which corresponds to the curve of the plantar arch, the concavity of which is downwards) in the various positions of the foot, and thus render it also capable of supporting the arch during their action. This action of the muscles on the plantar fascia, and on the anterior pillar of the arch of the foot, as well as the action of the fascia upon the arch, are well observed in the foot of the opera dancer. Not only are these muscles numerous and powerful, but they are s placed as to act almost all of them from the same centre, an therefore with greater advantage, for strengthening the arch.

MOVEMENTS.—These are described under the followin sections.

The Metatarso-phalangeal Joint of the Great Toe.

Class, Diarthrosis. *Subdivision*, Ginglymus.

The metatarso-phalangeal articulation of the great toe differ in some respects from the corresponding joints of the othe toes. The bones are on a larger scale; their articular surface are more extensive, and on the plantar aspect of the head o the metatarsal bone there is a smooth depression on each sid of the middle line, which receives a sesamoid bone. The ligaments of the articulation are like those of the correspondin joint of the other toes; but in place of a plate of fibro-cartilage, the sesamoid bones are substituted.

The SESAMOID BONES are two small hemispherical bodies developed in the tendons of the flexor brevis pollicis muscle, and which are situated, one on each side, in the depression on the plantar aspect of the head of the metatarsal bone. Their convex sides are directed downwards, and their flattened articular surfaces, which are free to play upon the metatarsal bone, look towards the cavity of the joint. They are united to one another by strong ligamentous bands, the fibres of which take a transverse direction, and the under surface of the band is smooth, and forms part of the channel along which the long flexor tendon plays. Anteriorly, the sesamoid bones and their uniting ligament are connected by short strong ligamentous fibres to the base of the phalanx; and posteriorly, by somewhat looser fibres, to the head of the metatarsal bone beyond the articular surface. On their sides which look away from one another, the sesamoid bones are connected with the lateral ligament, and with the sheath of the flexor tendon, in the same way that the sesamoid plates or fibro-cartilages of the other joints are. Thus these bones of the great toe, like those of the thumb, are surrounded by ligamentous fibres on all sides, except towards the joint, and by means of the fibres they are held to the phalanx and metatarsus, and help to enclose the cavity of the articulation.

These bones provide a shifting leverage for the tendons of the flexor brevis pollicis, and increase the angle of their insertion into the sides of the base of the first phalanx. They also give leverage to the tendon of the flexor longus pollicis.

THE ARTERIES OF THE METATARSO-PHALANGEAL JOINT OF THE GREAT TOE.—The dorsal artery of the great toe; and, on the plantar aspect, the plantar digital branches of the dorsalis pedis.

NERVES.—The anterior tibial on the dorsal aspect; and the internal plantar nerve in the sole. Occasionally the long saphenous nerve gives a branch to the inner side of this joint.

THE MUSCLES.—On the plantar aspect the following muscles are in relation to this joint: 1. The flexor longus pollicis passes over it to the base of the second phalanx. 2. The flexor brevis pollicis is inserted by two tendons into the sides of the base of the first phalanx. 3. The abductor pollicis is inserted with the inner tendon of the flexor brevis pollicis into the inner sesamoid bone and the inner side of the base of the first phalanx. 4. The adductor pollicis, with the outer tendon of the flexor brevis pollicis, into the outer sesamoid bone and outer side of the base of the first phalanx. 5. The transversalis pedis arises from the inner lateral metatarso-phalangeal ligaments of each of the four outer toes, and is inserted into the outer side of the plantar surface of the base of the first phalanx with the adductor pollicis.

On the dorsal aspect of the joint there are (1) the extensor proprius pollicis, and (2) the inner tendon of the extensor brevis digitorum, which is inserted into the dorsal surface of the first phalanx near its base.

The action of these muscles is sufficiently explained by their names. The *transversus pedis* acts on all the toes; by drawing the heads of the four outer metatarsal bones together, and the great toe towards the others, it strengthens the antero-posterior arch by holding the parts of its anterior pier together, and deepens the transverse arch in the same way. The long flexor and long extensor are the only two muscles which pass beyond the first phalanx, and they, by going to the base of the second phalanx, act first upon the inter-phalangeal joint, and afterwards upon the metatarso-phalangeal.

THE MOVEMENTS OF THE METATARSO-PHALANGEAL JOINTS consist of flexion and extension with some lateral motion, viz., abduction and adduction; and the combination of these four movements, viz., circumduction. Flexion is more free than extension, and is limited by the extensor tendon and dorsal ligament, and by the dorsal fibres of the lateral ligament extension is limited by the plantar articular structures, and by the plantar fibres of the lateral ligament, and by the flexor tendons.

Abduction and adduction are possible, owing to the shape of the articular surfaces of the bones, but are limited by the lateral ligaments and sesamoid plates. They are freest in the joint of the great toe.

The Inter-phalangeal Joints.

Class, Diarthrosis. *Subdivision*, Ginglymus.

The articulations between the first and second and the second and third phalanges of the toes are exactly similar to those of the fingers, with this important difference, that the bones are smaller, and the joints, especially between the second and third phalanges, are often ankylosed.

THE BONES.—The phalanges of the first and second row present at their distal extremities a smooth trochlear surface, consisting of a median depression with a slight convexity on each side of it. The articular surface is prolonged further on the plantar than dorsal surface, and is broader from side to side than from above downwards.

The phalanges of the second and third row present at their proximal ends a smooth articular facet, consisting of a slight concavity on each side of a dorso-plantar ridge. The ridge plays in the trochlea on the head of the bone behind it, and the little fossæ on each side of the ridge receive the condylar portions of the head of the same phalanx.

THE LIGAMENTS.—Two well-marked *lateral ligaments* pass one on each side of the joint, from a little rough depression on the head of the proximal to the rough border on the side of the base of the distal phalanx of the joint.

Glenoid Ligament.—On the plantar surface a *fibro-cartilaginous plate*, called sometimes the *glenoid ligament*, covers in the joint, and is connected along its proximal and distal borders with the phalanges by short ligamentous fibres, and along its lateral edges with the lateral ligaments. The plantar surface of these plates is smooth, and grooved for the flexor tendons.

Dorsal Ligament.—On the dorsal aspect a thin membranous ligament extends across the joint from one lateral ligament t the other beneath the extensor tendons, with the deep surface of which it is connected.

At the inter-phalangeal joint of the great toe there is frequently a small sesamoid bone which plays upon the plantar surface of the first phalanx, just as the sesamoid bones of the metatarso-phalangeal joint play upon the plantar surface of the head of the first metatarsal bone.

The Cutaneo-phalangeal Ligaments.—These, like the corresponding ligaments of the fingers, are well-marked bands of ligamentous fibres, which pass from the ridges on the lateral borders of the phalanges to the skin over the plantar and dorsal aspects of the inter-phalangeal joints. Those of the great toe are especially well developed; and those connected with the first joint more so than those inserted into the skin over the distal joints. The fibres over the first inter-phalangeal joint arise from the first phalanx, back as far as the sides of the metatarso-phalangeal joint, those of one side having passed on the dorsal side of the digital artery and nerve, decussate with fibres from the opposite side of the same phalanx before they are inserted into the skin over the first inter-phalangeal joint, on both the plantar and dorsal surfaces, but more particularly on the dorsal aspect.

The SYNOVIAL MEMBRANE is complete for each joint, and that belonging to the articulation between the first and second phalanges is ample, and even loose. Often those of the distal joints are completely or partially destroyed, as the joints themselves become more or less ankylosed.

THE ARTERIES.—Blood is supplied to these joints by little vessels which spring from the digital arteries, and run along in the sheaths of the tendons, one on each side, and then end in twigs, which penetrate the fibrous tissue and reach the synovial membrane. Others are given from the interosseous branches of the metatarsal artery; and in the case of the second and great toes from the dorsal artery of the great toe, and from the plantar digital branches of the dorsalis pedis.

NERVES are derived from the digital branches of the corresponding toes.

BURSÆ.—A bursa mucosa of the flexor tendons begins just above the first joint of each toe, and ends at the base of the last phalanx close to the insertion of the tendon.

MUSCLES.—Over the joints between the first and second phalanges there pass the tendons of the flexor and extensor muscles of the phalanges, some of which also pass over the joint between the second and third phalanges, to be inserted into the terminal phalanges; those which do not extend beyond the second phalanges are inserted into the bases of those bones. Into the base of the terminal phalanx of each of the four outer toes there is inserted the tendon of the flexor longus digitorum on the plantar surface, and into that of the great toe on the same surface is the flexor longus pollicis.

Into the base of the second phalanx on the plantar aspect of the four outer toes is inserted a tendon of the flexor brevis digitorum. Into the base of the second phalanx of each of the four outer toes, on its dorsal aspect, is inserted the central portion of the expansion of the extensor tendon, consisting of the extensor longus digitorum tendon and the lumbricales and interossei; and in the case of the second, third, and fourth toes, of a slip from the extensor brevis digitorum also. Into the base of the second phalanx of the great toe, on its dorsal aspect, the tendon of the extensor proprius pollicis is inserted.

MOVEMENTS.—Flexion and extension are the only movements permitted at these joints; the extent of these movements, so far as they are not limited by the stiffness which results from confinement within tight boots, and such-like abnormal restricting influences, is checked by the lateral ligaments and by the antagonism of the flexor and extensor muscles.

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